NASA TM X-73, 105

ESA-SL-75-2

FINAL REPORT

NASA/ESA CV-990 SPACELAB SIMULATION

A JOINT ENDEAVOR BY
NATIONAL AERONAUTICS & SPACE ADMINISTRATION
AND EUROPEAN SPACE AGENCY

(NASA-TM-X-73105) NASA/ESA CV-990 SPACELAB SIMULATION Final Report (NASA) 172 p HC $6.75 CSCL 22A

N76-26252

Unclas
G3/15 42282

by
John O. Reller, Jr.
NASA-Ames Research Center
Moffett Field, California 94035
January, 1976

JUL 1976
RECEIVED
NASA STI FACILITY
INPUT BRANCH

NASA TM X-73,105
ESA-SL-75-2

NASA/ESA CV-990
SPACELAB SIMULATION

A Joint Endeavor by
National Aeronautics and Space Administration
and European Space Agency

Final Report

APPROVED: D. Lord, NASA

APPROVED: B. Deloffre, ESA

January 1976

Although this simulation was jointly funded by NASA and ESA, the results obtained do not necessarily reflect the current policy of either agency with respect to Spacelab utilization.

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
TM X-73,105		
4. Title and Subtitle: NASA/ESA CV-990 Spacelab Simulation - Final Report		5. Report Date: January 1976
		6. Performing Organization Code
7. Author(s): Joint Endeavor - NASA/ESA Prepared by John O. Reller, Jr.		8. Performing Organization Report No.: A-6442
9. Performing Organization Name and Address: NASA Ames Research Center Moffett Field, Calif. 94035 and European Space Agency		10. Work Unit No.: 975-40-12-01
		11. Contract or Grant No.
12. Sponsoring Agency Name and Address: National Aeronautics and Space Administration Washington, D. C. 20546		13. Type of Report and Period Covered: Technical Memorandum
		14. Sponsoring Agency Code

15. Supplementary Notes

16. Abstract

As a result of interest in the application of simplified techniques used to conduct airborne science missions at NASA's Ames Research Center, a joint NASA/ESA endeavor was established to conduct an extensive Spacelab simulation using the NASA CV-990 airborne laboratory. The scientific payload was selected to perform studies in upper atmospheric physics and infrared astronomy with principal investigators from France, the Netherlands, England, and several groups from the United States. Two experiment operators from Europe and two from the U.S. were selected to live aboard the aircraft along with a mission manager for a six-day period and operate the experiments in behalf of the principal scientists. Communication links between the "Spacelab" and a ground-based mission operations center were limited consistent with Spacelab plans. The mission was successful and provided extensive data relevant to Spacelab objectives on overall management of a complex international payload; experiment preparation, testing, and integration; training for proxy operation in space; data handling; multiexperimenter use of common experimenter facilities (telescopes); multiexperiment operation by experiment operators; selection criteria for Spacelab experiment operators; and schedule requirements to prepare for such a Spacelab mission.

17. Key Words (Suggested by Author(s))	18. Distribution Statement
ASSESS Program Spacelab simulation Airborne science missions CV-990 airborne laboratory	Unlimited STAR Category - 15

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price*
Unclassified	Unclassified	171	$6.75

*For sale by the National Technical Information Service, Springfield, Virginia 22161

TABLE OF CONTENTS

TABLE OF CONTENTS - Concluded

NASA/ESA CV-990 SPACELAB SIMULATION
FINAL REPORT

A Joint Endeavor by
National Aeronautics and Space Administration
and European Space Agency

INTRODUCTION

Beginning in the 1980 time period, an advanced space transportation system will be used to conduct experiments in the space environment. This system will consist of a laboratory (Spacelab) carried into orbit by the reusable Space Shuttle. Spacelab is being developed and constructed in Europe under the direction of the European Space Agency (ESA). The Space Shuttle Orbiter is being built by the United States under management of the National Aeronautics and Space Administration (NASA).

Spacelab is being designed to be a versatile laboratory capable of accommodating a variety of experiments. The pressurized Spacelab module provides a shirtsleeve environment in which up to four payload specialists can operate experiments using the basic resources provided by the laboratory. Similarities between the method of experiment accommodation and operations planned for Spacelab and the methods used in conducting experimentation aboard aircraft by the NASA-Ames Airborne Science Office (ASO) led to the NASA-ESA Joint Mission, the sixth mission in the ASSESS (Airborne Science/Spacelab Experiments System Simulation) program. The vehicle chosen was the NASA CV-990 aircraft, which offers a laboratory environment of about the same size as Spacelab (fig. 1).

Previous ASSESS missions for the study of applications of ASO techniques to Spacelab operations are reported in references 1-11. The Joint Mission was the second in the series to utilize experiment operators (EOs); the first involved only a single experiment and two operators (refs. 9 and 10). This mission was the first large-scale simulation using the CV-990 with EOs and international participation, and it provided by far the most realistic Spacelab simulation to date.

Initial plans for the mission were discussed in February 1974. An exchange of letters between NASA and ESA in August 1974 formalized the Joint Mission. Six experiments were selected: three from Europe and three from the United States. The simulation mission took place at the NASA-Ames Research Center, Moffett Field, California, USA, between April 30 and June 24, 1975.

Spacelab payload manpower is limited to a maximum of four, which means that payload specialists often will be acting as proxy operators for principal investigators' (PIs) experiments. To test the concept of proxy operation, four experiment operators were selected and trained on the six experiments. During the simulation period, the EOs performed all experiment operations, including data taking, normal servicing, and minor repairs. For the entire

REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR

Figure 1.- CV-990 flying laboratory.

simulation period, the four EOs and the Mission Manager were confined to the aircraft and an adjacent sleeping area. The decision to confine the Mission Manager was in keeping with the mission plan to adhere closely to Airborne Science management techniques for this first full-scale simulation using the CV-990 aircraft. All communications with the outside world during the simulation period were handled by communications links (audio and video) simulating those planned for Spacelab. Scientific data were taken on all EO and PI flights.

English was the official language of the mission. Participants in the mission were British, American, French, Dutch, and German. With the exception of some members of the team from the Observatory of Meudon, all participants were fluent in English or sufficiently fluent to be understood as intended. No serious misunderstandings were noted at any time because of any language problem.

A concise statement of the major findings of the NASA-ESA Joint Mission is given in the Executive Summary (ref. 12). The present report develops and evaluates the main base of mission information, giving special emphasis to management techniques, payload development, operator training, and the overall performance of the mission organization during the simulation period. Results are summarized to highlight areas of particular relevance to Spacelab planning. The considerable body of detailed information available from the Joint Mission is incorporated into appendixes to this report that are published under separate cover, as listed in the Table of Contents herein.

Information for this report and separate appendixes has been gathered from several sources: the records of a team of observers who flew on all flights and observed mission activities in detail, mission operational records, mission planning documentation, information prepared by the PIs and EOs, an extensive debriefing following the simulation period, and individual interviews with mission participants. This report is a joint NASA/ESA effort, with inputs from a large number of persons from both agencies who were concerned with the mission. A roster of participants is provided at the end of this text.

MISSION OBJECTIVES AND GUIDELINES

The overall objective of the Joint ASSESS Mission was to evaluate a simplified management and implementation concept for conducting Spacelab-like experiment operations. The following were subordinate mission objectives:

1. To experience involvement in international cooperative payload activities
2. To evaluate experiment design approaches for Spacelab experiments
3. To determine the impact of operational requirements and procedures on Spacelab design
4. To evaluate payload and mission operations
5. To assess techniques for smooth integration of experiments and equipment
6. To analyze factors affecting selection and training of payload specialists, particularly in proxy experiment operation.

The Joint ASSESS Mission also served to encourage the development of a cadre of potential Spacelab experimenters. The mission did not address physiological or psychological factors.

The mission guidelines were designed to ensure a high degree of realistic simulation. The guidelines were constrained to the capabilities of the CV-990 aircraft, ASO practices, and the requirements for Spacelab as stated about one year before the ASSESS mission. The complete guidelines are provided in the Mission Operating Plan (appendix E) and are summarized below:

1. Authentic science to be performed
2. Six basic experiments to be operated (three European, three U.S.)
3. Ames ASO practices to be used as starting point for mission planning and execution
4. Participation of PIs in overall mission to be maximized
5. Four EOs (two European, two U.S.) to operate experiments in proxy role (i.e., on behalf of the PIs)
6. Simulation period to cover 5 days with a data flight each 24-hr period (experiments operated by EOs), with EOs and the Mission Manager confined to vehicle and living quarters
7. Unconstrained flights to be conducted for 2 weeks following the simulation period (experiments operated by PIs)
8. All supporting equipment, tools, and spare parts to be carried on board
9. Spacelab subsystems to be simulated where possible
10. Use of experiment support equipment to be shared
11. Communication to be limited to one video downlink, two 2-way voice links.

MISSION MANAGEMENT

Policy Management

Mission Planning Group

Basic guidance for the mission was provided by the seven-member Mission Planning Group (MPG), which comprised representatives from both NASA and ESA Headquarters organizations and from the Marshall, Johnson, and Ames NASA centers. Seven planning sessions were held between May 1974 and June 1975 at

which the MPG set the schedule, ratified the selection of experiments and EOs, developed the mission guidelines, and checked the status of the mission at all critical points. The detailed schedule developed by the MPG for the entire mission is shown in table 1.

Experiment Selection

Experiment selection started in late February 1974 in Europe as ESA solicited proposals from interested sponsors. Three were selected by early April on the grounds of developmental status, scientific desirability, and Spacelab compatibility. These experiments were approved by the MPG at their May 1 meeting and ESA monitored the experimenter grants. Selection of the three U.S. experiments followed in September 1974 with experiments chosen by NASA Headquarters to complement the European group. MPG approval was obtained prior to October 1, and the Mission Manager was assigned as technical monitor of experimenter grants.

Experiment Operator Selection

Four EOs were selected for this mission, two by ESA and two by NASA Headquarters. Selection was approved at the MPG September meeting. The EOs represented a broad spectrum of experience, ranging from that of a graduate science student to a scientist/astronaut, so as to provide insight on training requirements for subjects with different amounts of scientific background. Grants for the European and U.S. EOs were monitored by ESA and the NASA Mission Manager, respectively.

Implementation Management

Mission preparations and operations were implemented by the organizations shown in figures 2 and 3. During the simulation period, two members of the MPG, one from NASA and one from ESA Headquarters, were the overall mission authority (NASA/ESA panel) to ensure that the directives of the MPG were carried out and, if necessary, to make top-level policy decisions involving agency interests. The interaction between management and operations is discussed further under Mission Operations.

Mission Manager

The Mission Manager, from the ASO, was the single point of contact for all negotiations, decisions, and assistance in carrying out the mission from inception to completion. With the aid of one full-time assistant, he implemented the directives of the MPG; communicated with the PIs relative to their mission responsibilities; and handled all detailed planning of experiment integration, flight operations, and support activities. He was responsible, for example, for developing the Mission Operating Plan, the layout of experiments in the aircraft, the distribution of aircraft electrical power, the procurement of supplies and experiment-support equipment, arrangements for the use of the airborne digital data acquisition system (ADDAS), and development of preliminary flight plans to meet the PIs' scientific objectives.

TABLE 1.- SCHEDULE FOR NASA/ESA JOINT ASSESS MISSION

MILESTONES	1974											
	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER
PRELIMINARY CONCEPTS MEETING – ARC		▲										
MPG FORMED			▲									
ESA EXPERIMENTS SELECTED				▲								
MISSION PLANNING GROUP MEETING #1 NASA HQ. ESA EXPMTS. APPROVED					▲							
INVESTIGATORS' FAMILIARIZATION MEETING - ARC						▲						
MISSION PLANNING GROUP MEETING #2						▲						
NASA ESA MISSION AGREEMENT								▲				
SCHEDULE AND MISSION PLAN ISSUED								▲				
U.S. EXPERIMENTS SELECTED									▲			
MISSION PLANNING GROUP MEETING #3 - NASA HQ., EXPERIMENT OPERATORS SELECTED									▲			
EUROPEAN INVESTIGATORS' MEETING - NOORDWIJK (ESTEC)									▲			
EXPERIMENT RACKS SHIPPED TO INVESTIGATORS										▬		
U.S. INVESTIGATORS' FAMILIARIZATION MEETING ARC										▲		
NASA FUNDING TO U.S. INVESTIGATORS											▲	
EO TRAINING STARTS AT PI LABORATORIES											▲	
MISSION PLANNING GROUP MEETING #4 - PARIS											▲	
U.S. & EUROPEAN INVESTIGATORS' MEETING PARIS											▲	
TRAINING PLANS & EVALUATION CRITERIA DUE												▲
PRELIMINARY FLIGHT TEST OF TELESCOPE CAVITY												▲

TABLE I.- SCHEDULE FOR NASA/ESA JOINT ASSESS MISSION - Concluded

MILESTONES	1975 JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER
INVESTIGATORS SUBMIT ADDAS SOFTWARE REQUIREMENTS	▲											
MISSION PLANNING GROUP MEETING #5 – ARC		▲										
EXPMT. READINESS REVIEW FOR U.S. EXPERIMENTS. PRELIMINARY READINESS REVIEW FOR U.S. EOs.			■	■								
EXPMT. READINESS REVIEW FOR ESA EXPERIMENTS. PRELIMINARY READINESS REVIEW FOR ESA EOs.			■	■								
SHIPMENT OF ESA EXPERIMENTS TO AMES				■	■							
INSTALLATION OF EXPERIMENTS				■	■							
GROUND TRAINING OF EOs					■							
FLIGHT SAFETY BRIEFING					▲							
MISSION PLANNING GROUP MEETING #6 – ARC					▲							
CHECKOUT AND DATA FLIGHTS (4 FLTS)					■							
MISSION READINESS REVIEW FOR EXPERIMENTS AND EOs					▲							
FINAL MPG MEETING AT ARC						▲						
SIMULATION MISSION (5 FLTS)						■						
DEBRIEFING FOR SIMULATION PHASE						▲						
DATA FLIGHTS UNDER NORMAL CONDITIONS (7 FLTS)						■						
REMOVAL OF EXPERIMENTS						▲						
EXECUTIVE SUMMARY DRAFT							▲					
FINAL REPORT DRAFT												▲

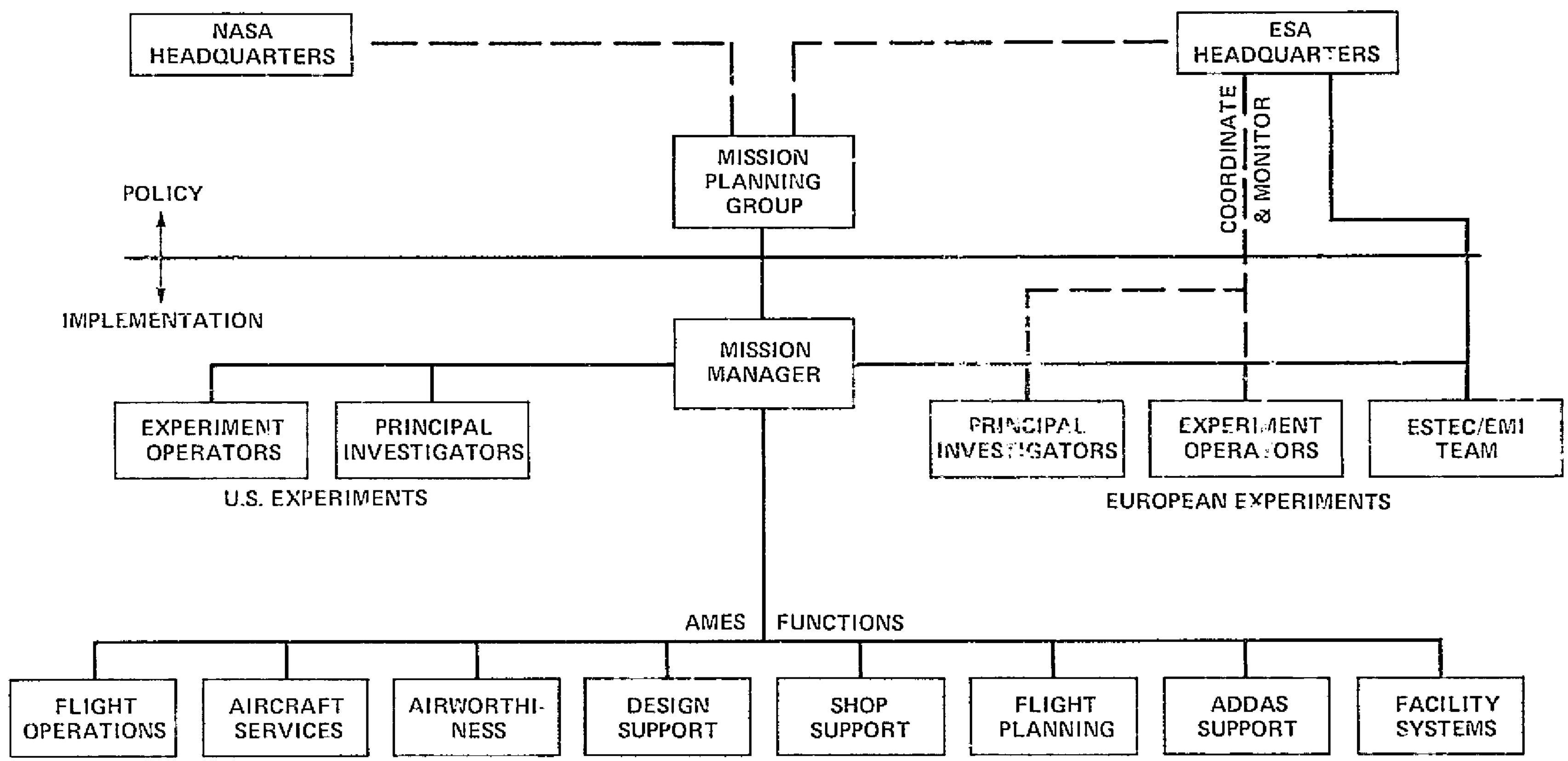


Figure 2.- Joint mission organization, preparation period.

ODUCIBILITY OF THE
INAL PAGE IS POOR

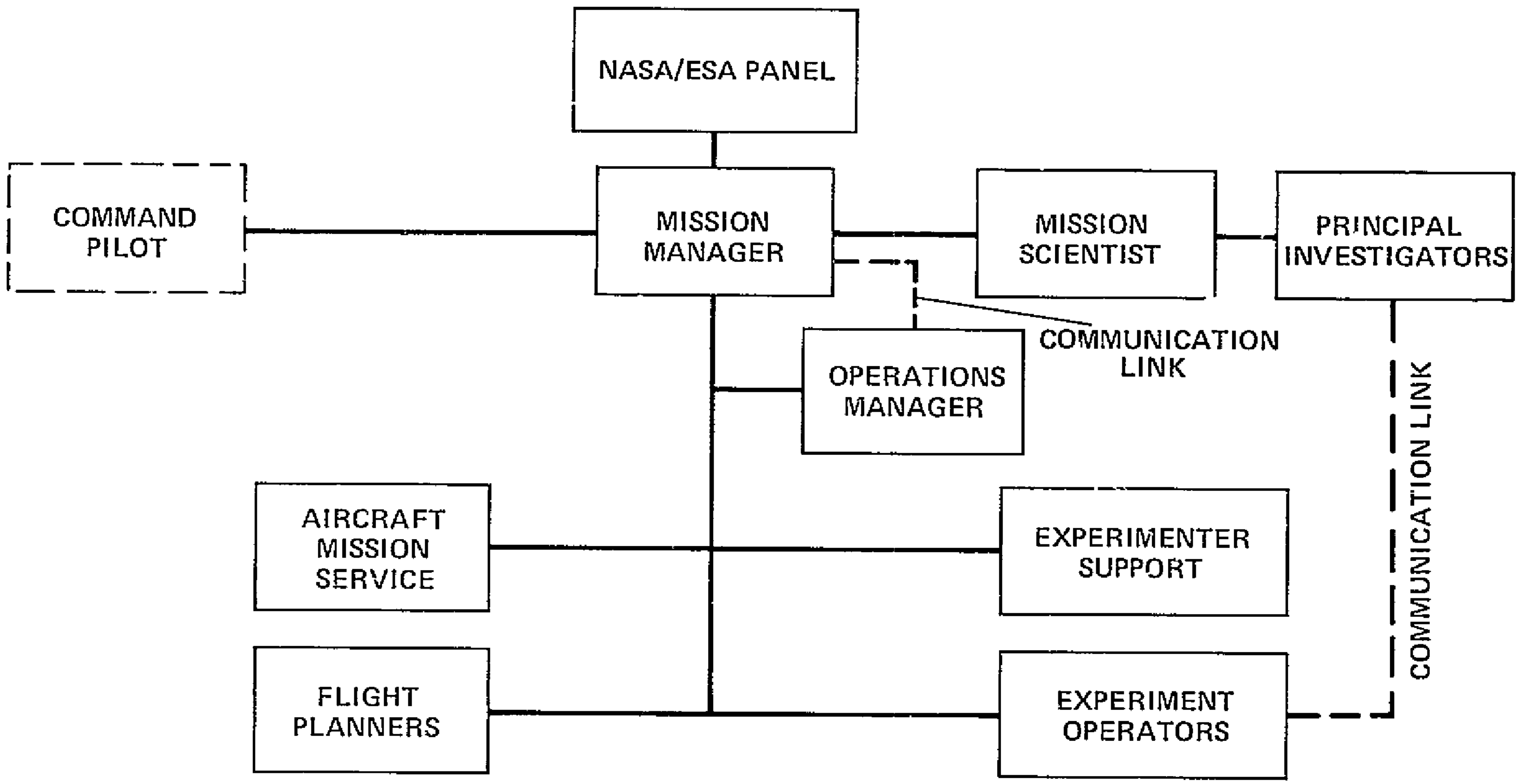


Figure 3.- Joint mission implementation organization, simulation period.

Day-to-day mission arrangements during the experiment integration, ground training, and flight periods were in the hands of the Mission Manager. During the integration period he and his assistant provided the point of contact between the experimenters and the shop personnel who fabricated special mounting brackets and performed the physical installation work in the aircraft.

The Mission Manager or his assistant directed operations in the aircraft during the ground training period, which simulated flight conditions with the aircraft parked so that astronomical observations were possible. They controlled the application of aircraft electrical power and coordinated the activities of the experimenters via the aircraft intercom system. During this time, they also worked with the PIs in setting up final details of desired flight plans for data flights.

On the four flights before the simulation week, the Mission Manager and his assistant were responsible for all flight details that pertained to the experimenters. Only the Mission Manager flew on the five flights during the week of the Spacelab simulation. He acted as the Spacelab Mission Specialist and was confined with the four EOs. For this period, the Mission Manager was assisted by the Mission Scientist, who was located at the Mission Operations Center. The PI data flights following the simulation period were directed by the Mission Manager and his assistant as in the first four flights.

The Mission Manager was not involved in detailed planning for the electromagnetic interference (EMI) measurements, which were made under the direction of ESTEC engineers before and after the simulation period. He did, however, arrange for space for one rack of instrumentation and schedule the EMI tests so that they did not interfere with other mission functions.

Mission Scientist

The Mission Scientist was selected from the ASO to work with the PIs during the simulation period. He was the "on-ground" coordinator and arbiter of science planning for the simulation flights; final approval of the unified flight requirements remained with the Mission Manager. This delegation of responsibility relieved him of much planning detail, reduced the number of active interfaces demanding his attention, and allowed flight operations planning to begin early in the day when the confined crew was still asleep.

EO and PI Roles

During the preparatory period of the mission, the PIs' primary responsibility was the development and fabrication of their experimental equipment. A special responsibility of the PIs for the Joint Mission was the development and implementation of training plans for the EOs. During the experiment integration period, the individual PIs again had primary responsibility for each experiment. The EOs assisted them in various ways as needed and used this period to further their familiarization with the equipment. After the experiments were installed on the aircraft, the EOs assisted the PIs in the checkout process, which was followed by a period of experiment

operation on the ground. The latter was intended primarily for PI instruction of the EOs in experiment operation, but the time was largely usurped by the PIs for final experiment alignment and checkout.

The PIs whose experiments involved more than one organization had the additional responsibility of coordinating the separate portions of their experiment. For the Meudon/Groningen portions of a three-way cooperative effort, this task generally was performed satisfactorily, except that the third participant (from Ames) was not informed about an interference with the dewar mounting that was discovered by the European coexperimenters. The Ames experimenter, who also had to attach a dewar to the Meudon telescope, rediscovered the difficulty much later. The JPL/Alaska/Colorado experiment, involving three widely separated organizations, suffered from a lack of communication among the participants. Mechanical mounting problems were not settled until after the start of the experiment integration period, despite extreme effort by the Mission Manager.

Experiment operation during the simulation period was the responsibility of the EOs. The PIs on the ground planned the observations for each flight and analyzed the data from each in a preliminary manner as a guide to planning for the following flight. During the data flights following the simulation period, the PIs operated their experiments in the usual manner. On a few of these flights, one or more of the EOs flew as a member of a PI team and assisted in experiment operation.

Mission Operations Manager

The Mission Operations Manager directed a ground-based mission operations center (MOC), which was set up only for the simulation period and staffed 24 hr per day. The MOC housed the Mission Operations Manager, the PIs, the Mission Scientist, and the NASA/ESA panel (fig. 4). The operations manager also was responsible for the maintenance and operation of the communications with the aircraft, and the provision of necessary supplies such as cryogenics and meals for the confined personnel. He led the daily debriefings before and after each flight and was responsible for the transfer of data between the aircraft and the ground.

Mission Documentation and Reviews

Documentation

The program was operated with a minimum of documentation. Solicitation of ESA experiments was by formal Announcement of Flight Opportunity (AFO) in late February 1974. NASA Headquarters solicitation was conducted informally among interested members of the scientific community. Experimenters submitted proposals describing their experiments and objectives for consideration. Successful proposers were notified by letter from ESA or NASA.

The two control documents were the CV-990 Experimenters' Handbook (ref. 13) which is similar to the Spacelab Payload Accommodation Handbook (ref. 14),

(a) PI communications area during preflight meeting.

(b) PI office area.

Figure 4.- Mission operations center.

REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR

and the Mission Operating Plan (MOP), prepared by the Mission Manager. The CV-990 Experimenters' Handbook, which was given to all experimenters soon after their selection, describes the aircraft and its facilities, specifies special requirements to be met by the PI on the mounting of the equipment in the aircraft, and gives a general description of the aircraft as a laboratory environment. This document provided sufficient information on matters of general interest but lacked certain specific information on interface control. In particular, safety requirements were not covered in sufficient detail to enable the first-time experimenter to proceed with confidence, and it was necessary to seek clarification from the Mission Manager. The MOP detailed the experiments to be flown, and described the mission management and organization, following the directives of the MPG. The MOP was issued in November 1974 for distribution at the November MPG and Experimenters' meeting in Paris. A revised plan was issued in January 1975. Significant mission documentation is reviewed in appendix E.

Implementation documents were initiated by the Mission Manager, and by the PIs at his request. Two Experimenters' Bulletins were issued in March and April 1975 to update mission plans and progress; to outline the information that would be needed for the experiment readiness review; to request final status on experiment support required from the airborne central data system, flight data systems, and aircraft electrical power systems; and to review special ASSESS-related information requests. Other management documents were aircraft flight plans, approvals by the Airworthiness and Flight Safety Review Board, an experiment integration schedule, and various Ames orders and records.

Implementing documents requested of the PIs dealt with experiment accommodations and EO training. Preliminary sketches of the assembled experiment and component descriptions were due in July, with detailed drawings (or sketches) and stress analyses of mounting hardware in early December. Documentation of software requirements for the onboard data system and ASO-supplied support equipment were to be completed by February. EO training plans, evaluation criteria, and training milestone charts were requested by mid-December.

ASSESS-specific documentation that had no direct bearing on the conduct of the mission was deferred until arrival at Ames. The EOs, with the aid of the PIs, prepared extensive detailed information on the experiments during the installation and checkout period. This information included experiment development descriptions, changes made for this mission, lists of individual components with their dimensions and electrical parameters, and special tool and supply lists for each experiment. The EOs, with PI assistance, also prepared detailed procedures for the operation of the experiments.

Reviews

Four management reviews of mission preparations were conducted covering all aspects of the operation, from the individual experiment to the conduct of the overall mission. Their subjects and timing were as follows:

1. Experiment readiness reviews (ERR), late March to early April
2. Flight safety briefing (FSB), April 20
3. Airworthiness and Flight Safety Review Board (AFSRB), May 16
4. Mission readiness review (MRR), May 29.

Experiment Readiness Review. Early ASSESS program experience demonstrated the need for a program milestone, scheduled about one month prior to experiment shipment, to assure timely completion of experiment preparation. Accordingly, the ERR concept (a Mission Manager function) was applied in two Spacelab simulation missions prior to the Joint Mission (refs. 8-10). By the end of March each experiment for the Joint Mission was to be assembled, tested, and integrated into the standard experiment racks. The PIs were also to provide final definition of GFE support requirements, experimenter-provided supplies and test equipment, and procedures to counteract equipment malfunctions during the mission. The ERR included a review of EO training status and final program content to assure adequate preparation, particularly with respect to integrated mission simulation. Experiment readiness reviews are considered in more detail in the next section.

Flight Safety Briefing. The FSB is a normal safety procedure for all airborne science missions. This briefing was required for all Joint Mission personnel who would fly in any phase of the mission, and served to acquaint them with normal safety practice in the aircraft environment, to define procedures developed to assure the safe operation of specific experiments, and to explain and demonstrate the use of emergency equipment. The FSB was chaired by the Mission Manager and scheduled for the later stages of experiment integration when safety equipment had been positioned in the cabin.

Airworthiness and Flight Safety Review Board. The AFSRB is the final authority on safety for all airborne science missions and must give written approval before flights begin. The board consists of experts in several pertinent disciplines appointed by Ames management, and has broad overall responsibility for all aspects of flight safety. Safety preparations for the Joint Mission followed normal ASO procedures. Day-to-day decisions were made by the Mission Manager with the support of the Airworthiness Assurance Office (AAO) of the Ames Aircraft Operations Division. Unique experiment requirements, special procedures, and long lead-time designs were reviewed by the board well ahead of the formal premission review on May 16. At the May 16 meeting, the Mission Manager reviewed the details of each experiment installation, the flight schedule and associated plans, and any special arrangements (e.g., living accommodations) peculiar to the mission. His presentation was supported by design specialists, flight planners, operations personnel, and the command pilot for in-depth response to board inquiries. PIs and EOs were not present at the review. As a result of excellent coordination among the Mission Manager, AAO engineers, and the AFSRB during earlier stages of mission preparations, the overall plan was accepted by the board with only minor changes related to the safety of the confined simulation crew.

Following the third flight of the presimulation checkout period, the board met again to consider procedural changes requested by the Meudon PI to

facilitate operation of the Meudon/Groningen experiment. Approval was given to operate with a mylar cover over the telescope port and for limited overwater flights.

Mission Readiness Review. The MRR was held by the Mission Manager on May 29 to assess the status of experiments and EOs at the completion of the scheduled checkout and training flights. With few exceptions, neither PIs nor EOs had completed their preparations. By urgent request, an additional equipment checkout flight was scheduled for the PIs, while arrangements were made for intensive on-ground training of EOs on each of the three days remaining before the simulation period. This review is discussed in more detail under MISSION GROUND OPERATIONS.

PAYLOAD DEVELOPMENT

A nucleus of three European experiments was chosen on the grounds of developmental status, scientific desirability, and Spacelab compatibility. This payload nucleus was complemented by the choice of three compatible U.S. experiments, one of which comprised three individual experiments that were developed independently but intended for operation as a single integrated experiment. The sharing of basic experiment hardware created complex requirements for programmed interchange of sensors on a priority basis by the EOs during the flight period, just as may be expected on Spacelab.

The six experiments are summarized in table 2. Two involved more than one research organization. The first was a spontaneous alliance of coinvestigators, while the second resulted from NASA's combining two separate proposals. This section provides a brief discussion of objectives, planning criteria, and procedures for experiment design and development; a description of each experiment, its preparation for the mission, and its readiness review status prior to shipment to Ames; and a brief evaluation of management effectiveness in the planning and development of the overall mission scientific payload.

Objectives, Guidelines, and Procedures

One of the objectives of the Joint ASSESS Mission was to "evaluate . . . design approaches for Spacelab experiments" in terms of the overall method applied and the instrumentation design. The experiment development period extended from the selection date until the experiment readiness review (ERR), at which time all equipment changes, component verification, assembly, and bench testing of the complete experiment were scheduled for completion. Integration into standard racks would be completed, or nearly so, with only such tasks as final adjustment and calibration remaining to be done. In Spacelab terminology, this is the Level IV integration task as defined in the section on MISSION GROUND OPERATIONS in this report.

Planning Criteria

PI planning was guided by several principles and requirements, summarized below:

TABLE 2.- EXPERIMENTS FOR CV-990 NASA/ESA ASSESS MISSION

Code number	Organization	Instrumentation	Measurement
E1	Observatoire de Meudon CNRS-Verrières University of Groningen	30-cm Cassegrain telescope with filter wheel IR photometer Cooled Ge bolometer	High-resolution mapping of dark clouds and HII regions
E2	Queen Mary College	Polarizing interferometer Cooled Ge bolometer	IR emission spectrum of upper atmosphere
E3	University of Southampton	Imaging Isocon TV camera IR photometer All-sky camera	Observation of OH airglow clouds
US1	NASA-Ames Research Center	30-cm Cassegrain telescope (Meudon) with variable filter-wedge spectrometer Cooled InSb detector	Near IR spectra of Venus and Late type stars
US2	NASA-Jet Propulsion Laboratory University of Alaska University of Colorado	Tunable acousto-optical filter spectrometers (2) with telescopes 1-m Ebert-Fastie spectrometer, telescope and stabilized mirror 12.5-cm Ebert-Fastie spectrometer	UV, visible, and near IR measurements of atmospheric transparency, solar flux, planetary atmospheres, and interstellar molecules
US3	University of New Mexico	35-mm camera with IR image intensifier 16-mm camera with image intensifier for time-lapse photography Filter-wheel IR photometer	IR photography of OH airglow clouds

1. Modifications necessary to meet aircraft and/or Spacelab simulation constraints must not invalidate the scientific significance of the experiment.

2. Manpower required to operate and maintain the experiment should be compatible with EO assignments and time-sharing agreements.

3. Controls, status indicators, and monitor devices should be centrally located for ease of operation. It is expected that experiment groups under the purview of one EO will be controlled from one location. It is suggested that elements of control and status for the entire payload be coordinated for display on one central panel.

4. Experiments should utilize the central airborne computer for recording and processing data, insofar as this facility will benefit the overall science effort.

5. Experiments should be configured to protect against electromagnetic interference (EMI) from aircraft support and communication systems, and from other experiments in the payload. Definitive measurements of the EMI environment should be made for the integrated payload.

Development Requirements

Table 3 summarizes the initial status and subsequent development of the experiments; for clarity, the three parts of experiment US2 are listed separately for a total of eight table entries (individual experiments). The initial status of the selected experiments varied widely from design studies to equipment with several years' history of operation. Three of the eight individual experiments in the payload were proposed by experimenters who had been involved in previous airborne research, with this or a similar experiment. Seven normally required more than one operator.

The scheduled period of development, from selection to the ERR, was 11 months for ESA and 7 for NASA experiments and experimenter teams ranged from 1 to 13 persons. Only one group finished on time, although four others were reasonably close to completion of their development tasks. The two U.S. groups that developed flight experiments from "scratch" required more than 7 months development time. As the on-site integration and checkout period drew to a close, some two months after the ERR, seven of the eight individual experiments were in full operation, although two had not yet achieved the desired quality of scientific measurements. The eighth experiment was partly operational, but continued to have problems to the very end of the post-simulation period.

Table 3 also indicates the categories of experiment development effort that were of greatest concern to the PIs: improving experiment science potential, meeting flight environment constraints, and providing data-handling methods for PI and EO evaluation. Most of the PIs introduced some automation to reduce EO workload. The Meudon/Groningen group was outstanding in this effort and succeeded in reducing the manpower required for experiment operation from three to one. However, relatively little was done to ease EO tasks by centralized controls and simplified servicing/maintenance operations. Much needed planning for EO and equipment time sharing was virtually ignored by the PIs until the last few days before the simulation period began.

TABLE 3.- OVERVIEW OF EXPERIMENT DEVELOPMENT

Experiment	Status when selected: Concept (C) or hardware (H)	First operated	Ground or flight use	Number of operators required	Previous similar expts.; ground or flight	Effort and schedule: Time available, months	Size of team	Status at LRR 1 to 6	Completed by A to E	Direction of development effort: Flight constraints	Improve science potential	EMT compatibility	EO Performance: Automatic functions	Central controls	Ease during	Service and maintenance	Operations monitors	Data handling: Central facilities	Local processing	Quick look	PI evaluation	Postflight processing
E1	H	1971	G	3	G	11	13	6	E	•	•	••	••	•	0	0	•	•	••	•	•	0
E2	H	1972	G	2	F	11	4	5/6**	B	•	•	••	0	0	0	•	•	••	0	••	••	••
E3	H	1973	G	2	---	11	3*	2/3**	C	••	••	••	•	•	0	•	0	•	•	•	••	0
US1	H	1972	F	2	F	7	2*	2	C/D	0	0	•	0	0	0	0	0	•	0	•	•	•
US2	C (JPL)	1975	None	2	---	7	3	1	E	•	••	0	0	0	0	0	---	••	0	•	•	•
US2	C (Alaska)	1975	None	2	F	7	4	4	E	•	•	0	•	0	0	•	•	••	••	••	•	0
US2	H (Colorado)	1974	G	1	---	7	1	5	C/D	•		0	•	0	0	0	0	0	••	•	•	0
US3	H	1975	None	2	G	7	2	3	C	•	••	•	•	0	•	0	0	0	0	•	••	•

(1) Experiment primary hardware [illegible] complete, component testing started.

(2) Component tests completed, assembly started.

(3) Bench assembly completed, system tests started.

(4) Software/hardware integration complete.

(5) System tests done, Level IV integration started.

(6) Level IV integration done, final tests completed, ready to ship.

(A) LRR date

(B) Shipping date

(C) End of integration/checkout

(D) Post-simulation period

(E) End of mission

•• Much

• Some

0 Little or none

* PI also

** Refers to level IV integration

REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR

Experiment Readiness Reviews

As in earlier Lear Jet simulation missions (refs. 8, 9, 10), a formal procedure of reviewing experiment readiness was followed. One such review for each experiment took place prior to shipment to Ames. The main objectives were:

1. To establish readiness status of the experimenter in terms of available hardware, layout and mounting within aircraft racks, mounting provisions for sensors and equipment outside standard mounting racks, system checkout, and safety

2. To determine support equipment to be provided by the PI and by the ASO

3. To define final interface requirements for power and data

4. To determine flight route requirements

5. To review EO training status.

These topics were set down in a detailed outline and circulated to the PIs in advance of the meeting to make them aware of the type and level of detail of the information to be requested of them.

In the United States, the ERRs took the form of conference telephone calls to the experimenter at his home laboratory, and included the Mission Manager, his assistant, and the responsible Ames engineering and safety personnel. In Europe, the reviews were conducted at the various laboratories by the chief of the ESA ASSESS planning group. No engineering or safety consultants from Ames could be included in the ESA reviews, however, because of NASA travel budget restrictions, and basic structural design errors were still present in some experiments when shipped. As a result, some mounting fixtures and experiment hardware required modification after receipt at Ames. These last minute modifications were performed successfully, showing that if similar situations should arise during Spacelab preparations, effective measures could be taken if adequate support personnel were available.

Even though the reviews were held in late March and early April, only three or four weeks before shipment to Ames, the focus of the reviews was not a positive statement of present experiment readiness (as it should have been), but rather was an assurance that remaining tasks could be completed in time to meet the integration schedule at Ames. PI responses to this inquiry were affirmative; nevertheless, most experimenters continued with modifications and adjustments up to the beginning of the simulation period. At the time of the ERR, only the Meudon/Groningen and Queen Mary College experiments had been fully mounted in the ASO standard equipment racks.

The Experiments

Meudon/Groningen (E1)

Scientific discipline:	IR astronomy
Scientific objectives:	High-resolution mapping of dark clouds and HII regions
Participating organizations:	Observatoire de Meudon (France) CNRS-Verrières (France) University of Groningen (The Netherlands)
Primary instrumentation:	4-channel IR photometer mounted on 30-cm Cassegrain telescope
Observational bandwidths:	17-20 μm, 30-38 μm, 70-95 μm, and 114-196 μm

Description. This basic scientific experiment was designed to further understanding of early star formation from dark clouds of material that are strong IR emitters. The cloud near the star ρ Ophiuchi is an excellent subject for study because of its relative closeness and low temperature.

The experiment utilized the Meudon telescope and the Groningen photometer (fig. 5), both controlled by the experimenter's computer. The photometer was set to detect radiation in one of the wavebands noted above, and the region of sky near the telescope pointing direction was mapped by raster scanning the telescope. Then the photometer was automatically reset to another waveband and the process repeated. The detector was a germanium bolometer maintained at 2.4 K by a dewar of liquid helium. Incoming radiation was chopped by an oscillating secondary mirror. The detected signal was amplified and synchronously measured by conventional electronic circuitry. Data were recorded in digital format on magnetic tape. The open-port telescope pointed at 33° ± 4° and was gyrostabilized to an accuracy of 15 arcsec with 5 arcsec attainable by complex data processing. A TV camera and monitor were used for finding and tracking, and could be locked to a target for automatic tracking. The TV signal was also recorded on magnetic tape. A more detailed description of experiment components, the arrangement in the standard racks, the power required, etc., will be found in appendix B to this report, published under separate cover.

Development. The system consisted of a telescope mounted in a special cavity, four standard racks, and one low-boy rack. The telescope, its basic controls, and TV pointing and tracking system were originally developed in 1971. This experiment configuration was operated on more than 20 flights of a French Caravelle research aircraft in 1973 and 1974. Since normal crew complement on these flights was three experimenters, substantial additional automation was required for the Joint ASSESS Mission to permit operation by a single EO. Servo performance in the tracking loop was improved to require less attention to long-term drift; selection of tracking modes was automated with a single switch control; displays of experiment operational modes were improved; and a PDP-11 computer was added to operate on the data and to give a visual display of scanning information. Electronic components and panels were mounted with insulators to meet ESTEC EMI specifications; single-point

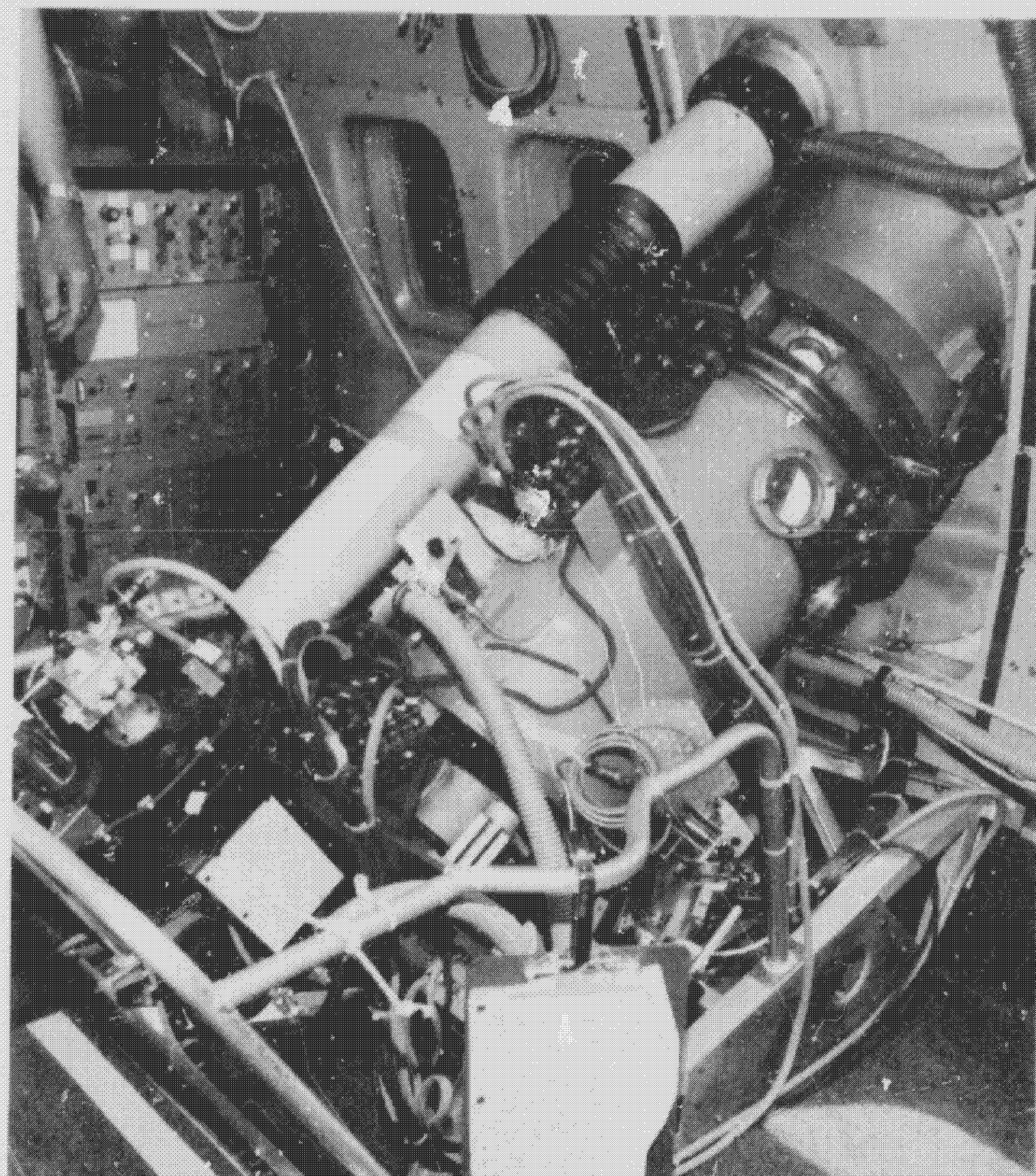


Figure 5.- Meudon IR telescope in overwing hatch.

REPRODUCIBILITY OF THE
ORIGINAL PAGE IS POOR

grounding was implemented. A new telescope mount was constructed to fit the overwing hatch of the CV-990 (fig. 6), and new support brackets for the telescope were fabricated to carry the weight of the device on the seat rails (fig. 7).

The Groningen detector system was originally used on a balloon-supported telescope. The only modification needed for this application was to make a new bracket to attach the detector/dewar to the French telescope.

The installation of this equipment in the Caravelle utilized conventional tall electronic equipment racks, permitting a centralized grouping of most controls. Use of the standard CV-990 racks for the Joint Mission, however, made it impossible to group all of the controls in a single location for efficient operation by a single EO. Thus, primary operating controls were centered in one location (fig. 8), with peripheral control groups for major subsystems. Telescope controls were grouped in a rack adjacent to the telescope (fig. 9) and detector controls were in a second rack (behind the operator). Other data system components were positioned in two other racks (figs. 10 and 11).

No problem from aerodynamic turbulence in the telescope cavity was anticipated on the CV-990 installation. Figure 12 is a photograph of the telescope port with the Meudon fence. As it turned out, there was a serious guidance problem caused by aerodynamic effects, that was resolved with a mylar cover on the port opening during the simulation period (fig. 13), and by the installation of an Ames designed aerodynamic fence (fig. 14) late in the postsimulation flight series.

Experiment Readiness Review, April 1. This experiment was well developed for airborne science at the time of selection and was completely assembled and operational in time for the ERR. No further development of electronic or other equipment was required during the integration period at Ames.

All subsystems had been tested in the laboratory and the dewar/photometer tested in flight for mechanical and electrical interference. Level IV integration with EMI isolation was nearly finished, and the only remaining work was the mounting of an analog and a video recorder on the low-boy rack. A maintenance plan was developed and implemented with spares and support equipment. GFE support requirements were clearly defined. PI concern with temperature and vibration in the aircraft environment could not be resolved until the checkout flights. Data logging was all self-contained, except that units peripheral to the aircraft central computer (ADDAS) were to be used to record one analog signal and to make hard copies of the CRT graphic display.

Both the primary and secondary European EOs had received considerable training prior to the ERR, and future sessions had been scheduled for their operation of the entire system. The two U.S. EOs were not available for instruction. The primary European EO requested that the PI prepare a data-logging sheet and establish a suitable format for star-recognition patterns. He felt capable of repairing the electronic equipment to the electronic card level and requested that the PI prepare that level of reference material for maintenance. Preliminary timelines were on hand, along with directions for evaluating data quality.

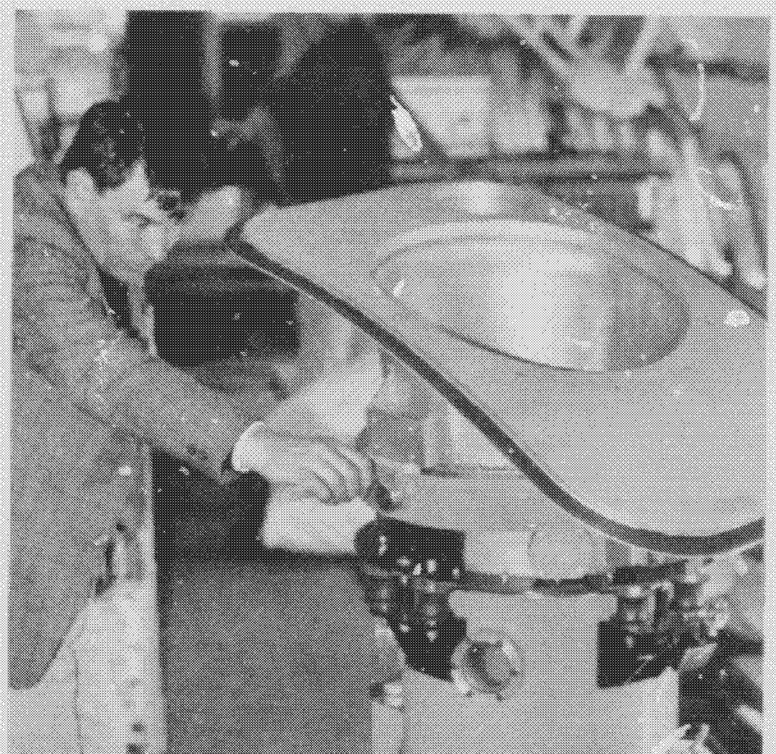


Figure 6.- Hatch plate on barrel of Meudon telescope.

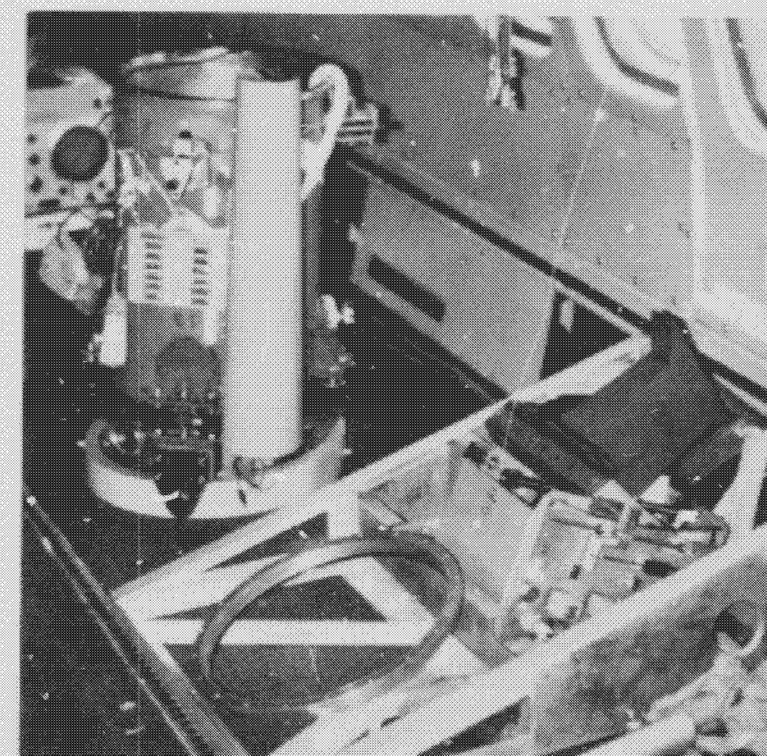


Figure 7.- Telescope support frame.

REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR

Figure 8.- Main control center for Meudon/Groningen experiment.

REPRODUCIBILITY OF THE
ORIGINAL PAGE IS POOR

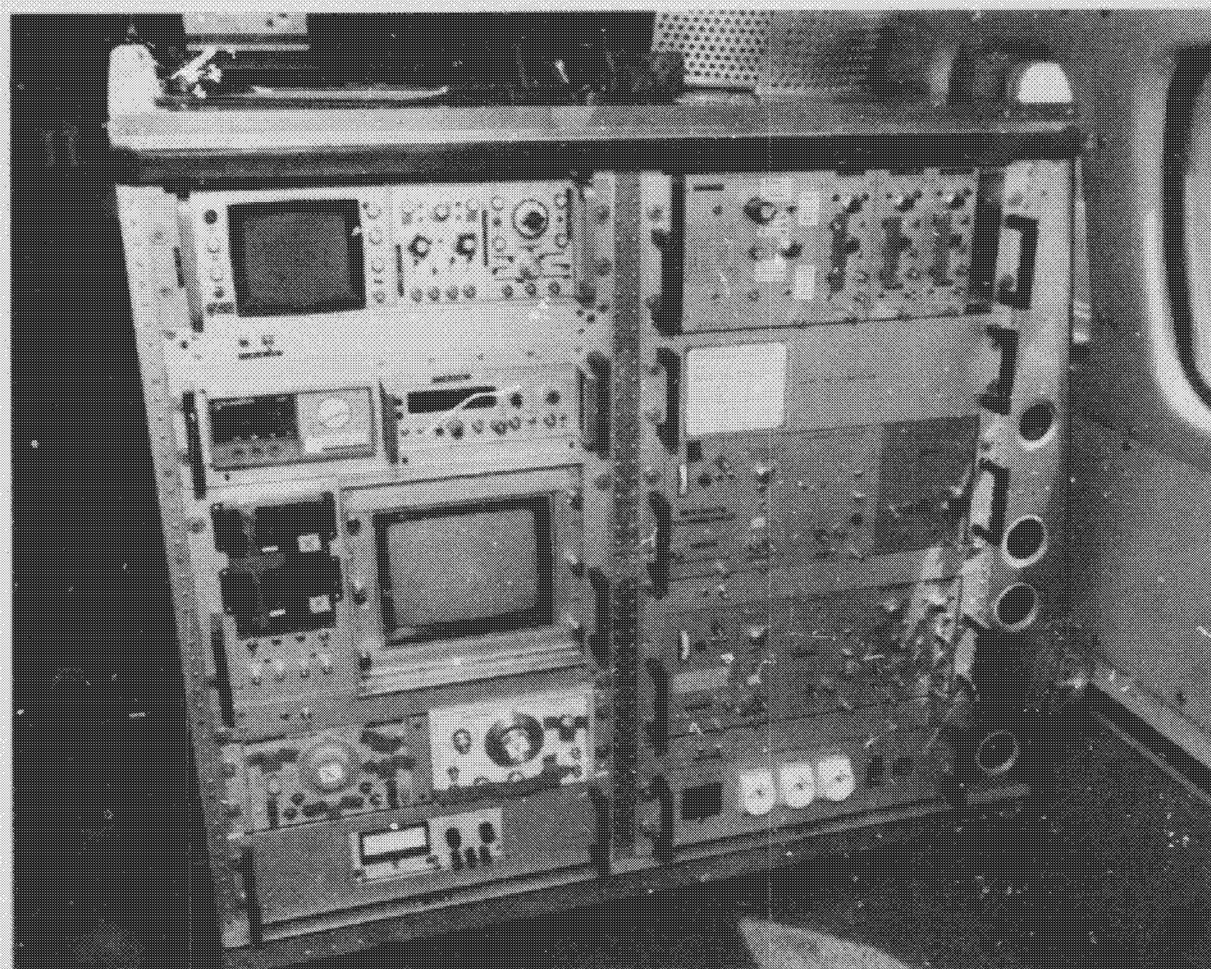


Figure 9.- Meudon telescope control rack.

...UCIBILITY OF THE
...NAL PAGE IS POOR

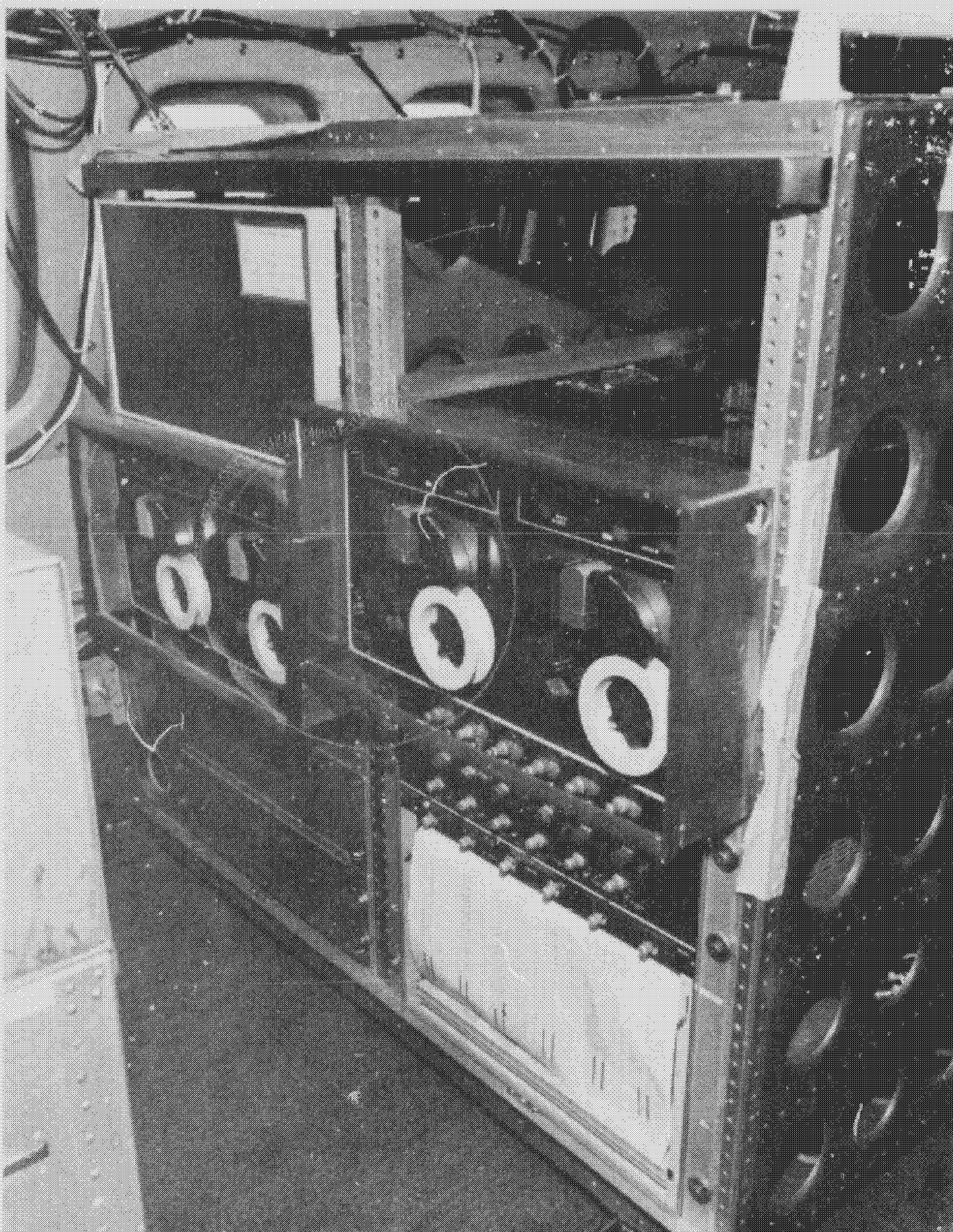


Figure 10.- Meudon computer rack.

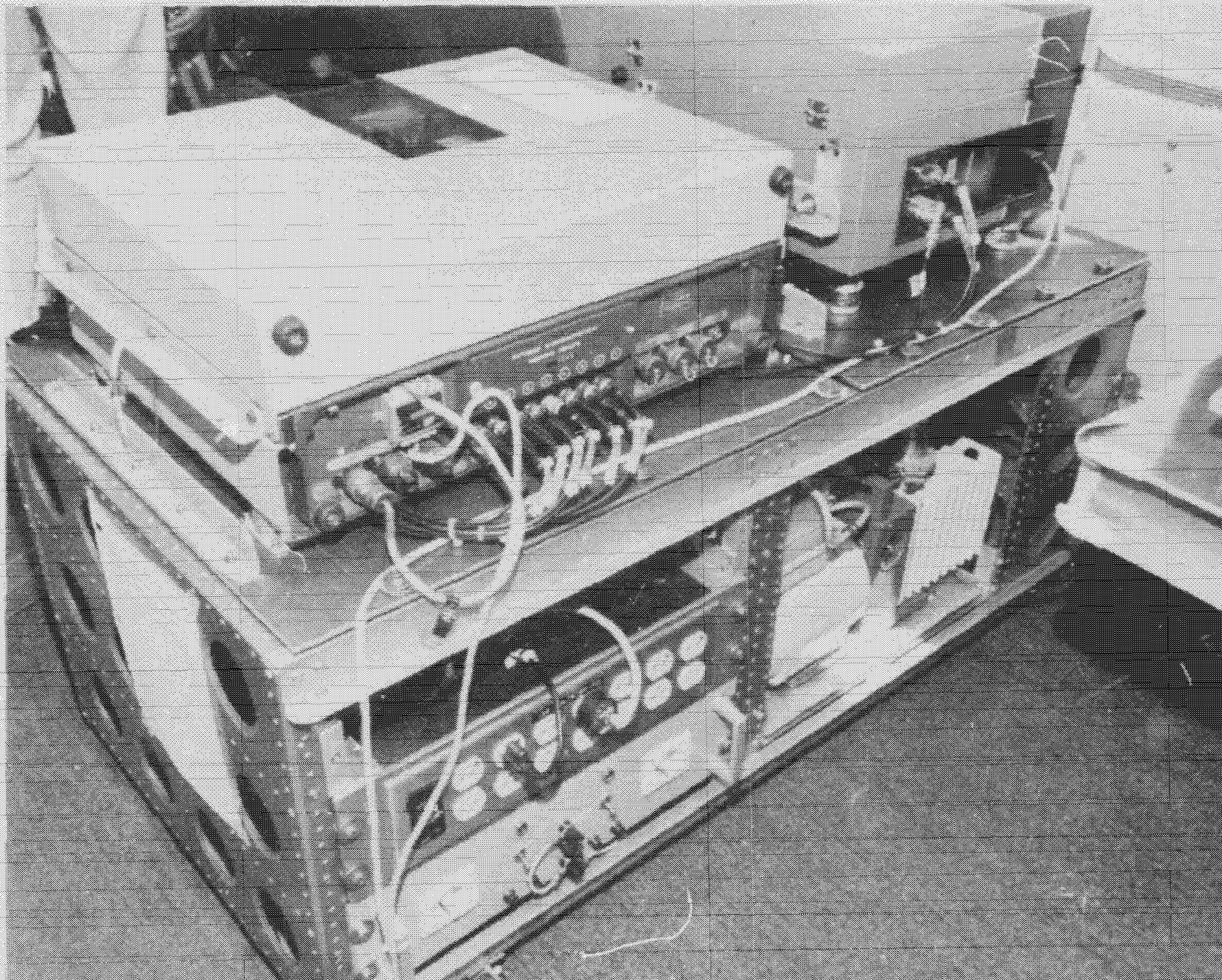


Figure 11.- Meudon/Groningen recorder rack.

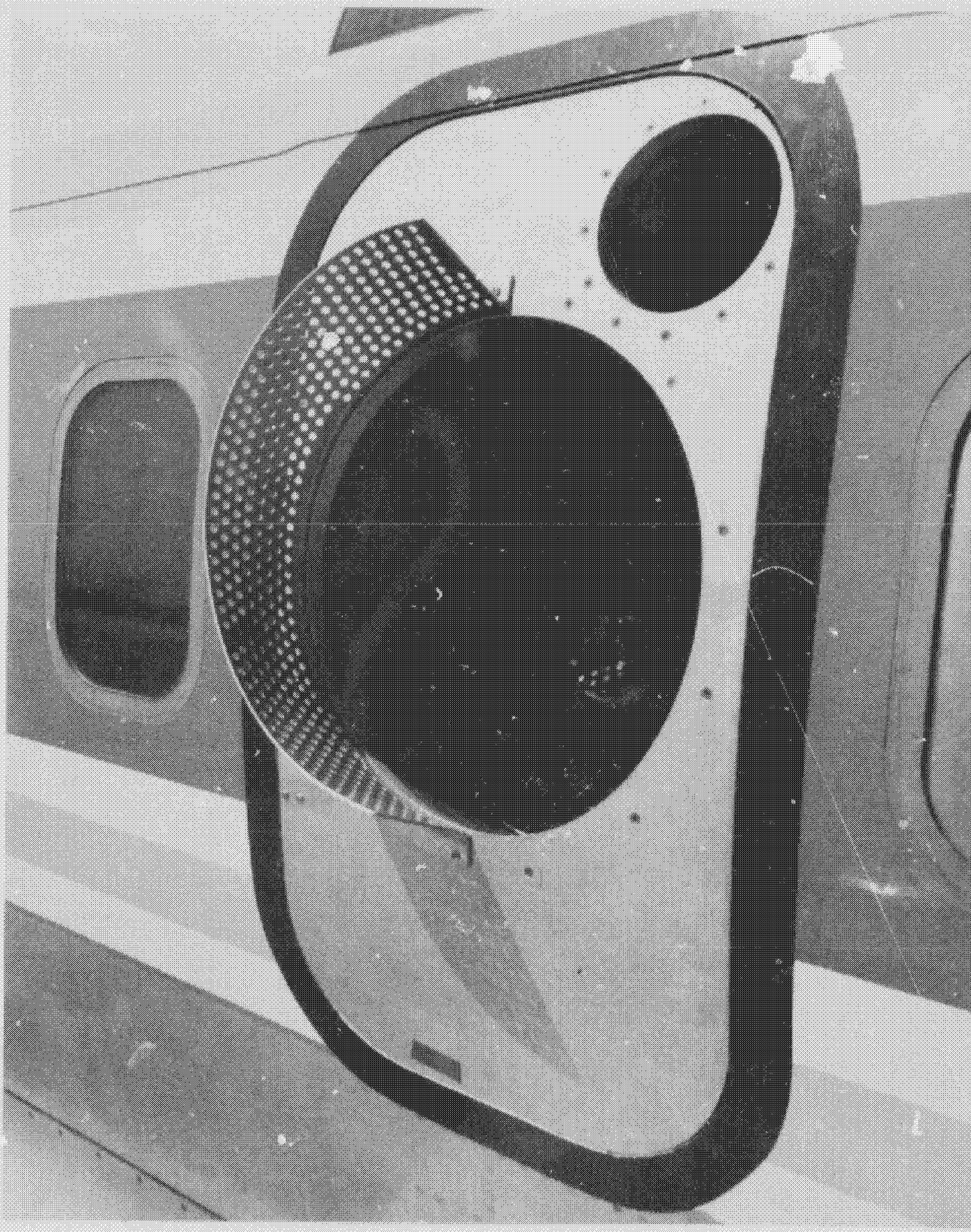


Figure 12.- Telescope port with aerodynamic fence.

REPRODUCIBILITY OF THE
ORIGINAL PAGE IS POOR

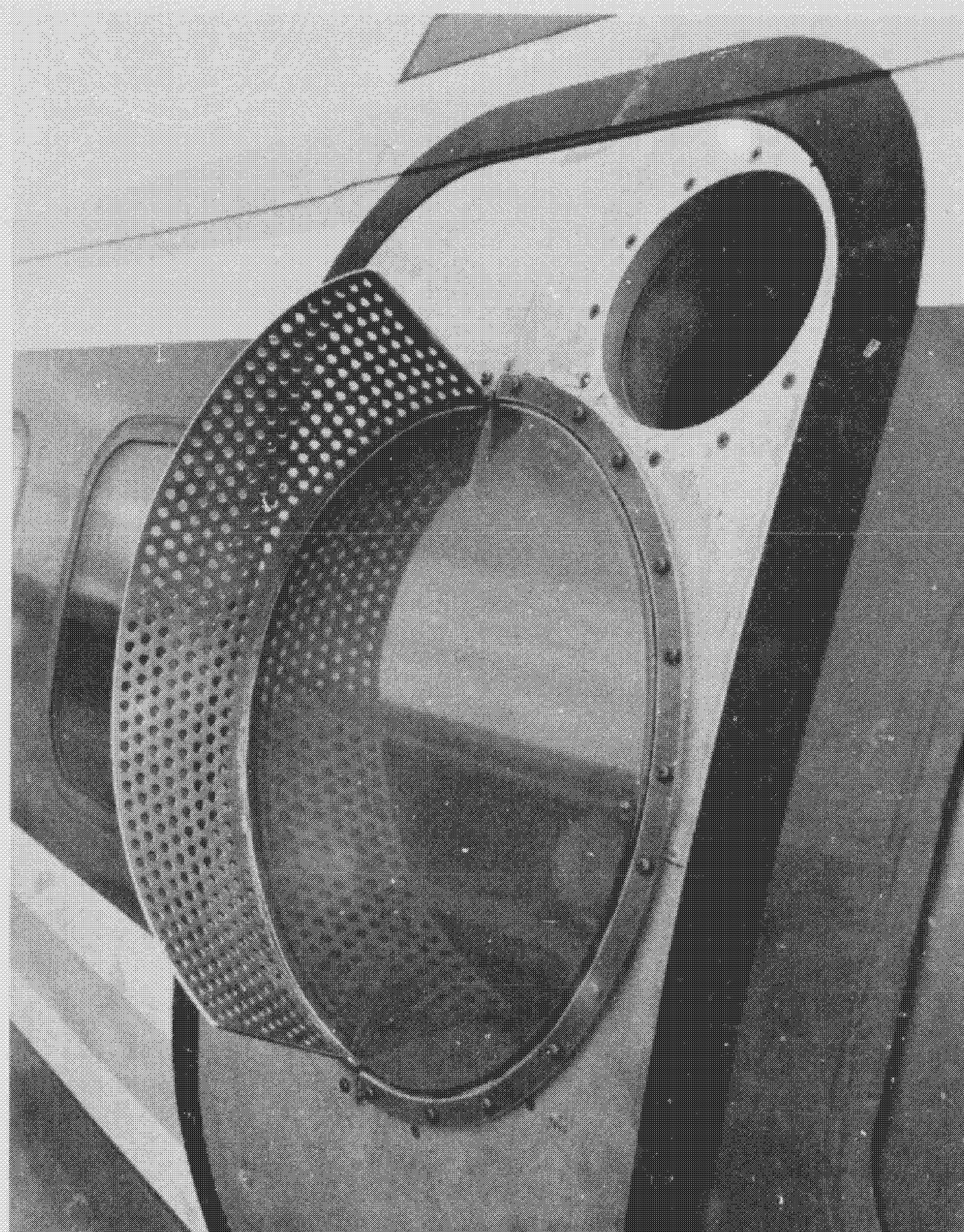


Figure 13.- Telescope port with mylar cover.

REPRODUCIBILITY OF THE
ORIGINAL PAGE IS POOR

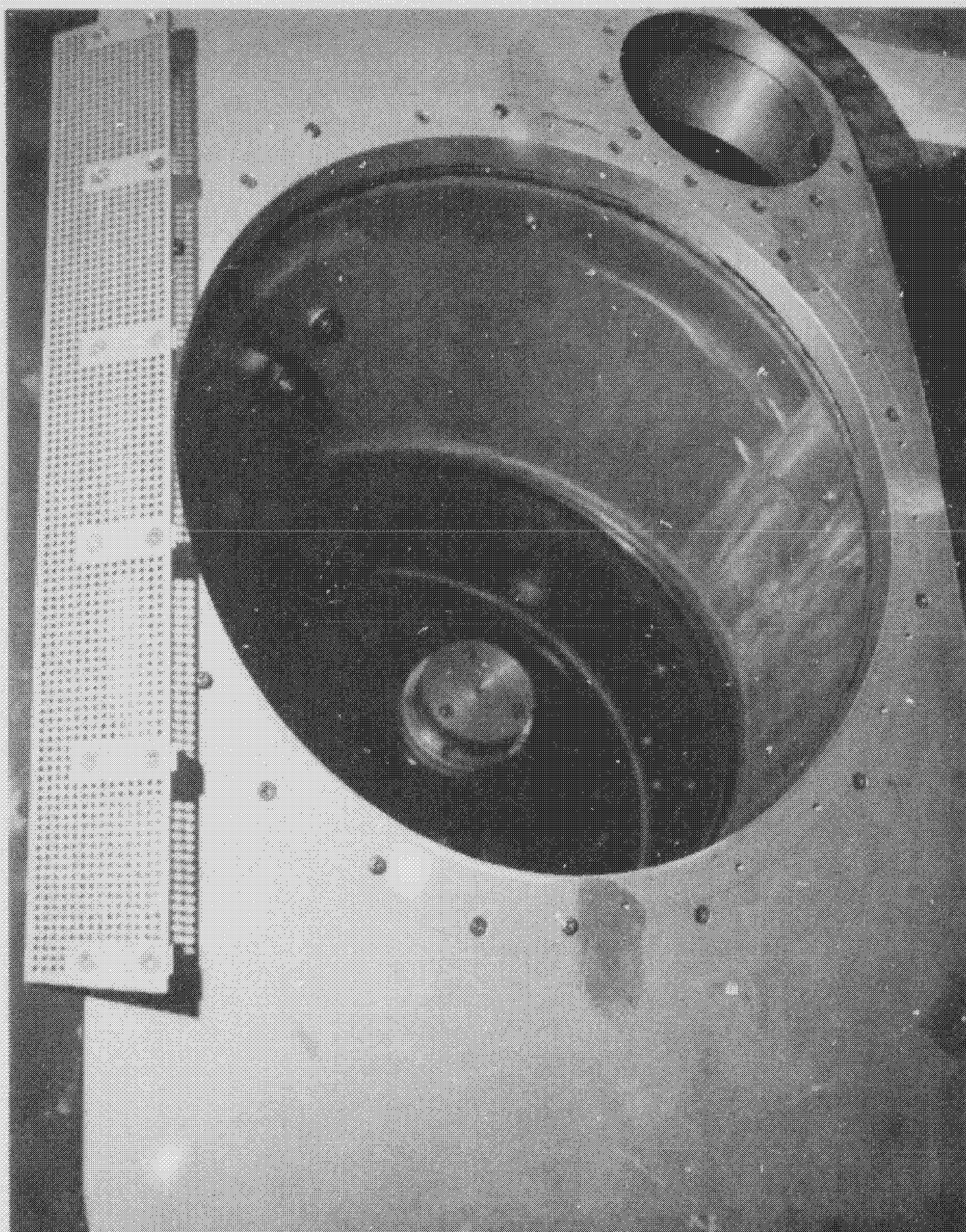


Figure 14.- Ames designed 30° ramp fence.

REPRODUCIBILITY OF THE
ORIGINAL PAGE IS POOR

Queen Mary College (E2)

Scientific discipline:	Atmospheric physics
Scientific objectives:	Emission spectra of the upper atmosphere
Participating organization:	Queen Mary College, University of London (England)
Primary instrumentation:	Polarizing interferometer (including internal temperature references)
Observational bandwidth:	40 μm to 2 mm

Description. This experiment provided absolute measurements of concentrations and temperatures of various molecular components of the atmosphere. The instrument was a two-beam interferometer based on polarizing optics. The two signals compared were the atmospheric emission and the calibration sources (alternately liquid nitrogen and water ice temperatures). A rotating polarizer, used as a chopper, produced an alternating signal proportional to the difference between incident and reference radiation. The signal was demodulated by standard methods to produce an interferogram; the desired spectrum is the Fourier transform of this interferogram. The detector was a liquid-helium-cooled (2 K) germanium bolometer.

The amplified and detected data signals were digitized and recorded on the aircraft ADDAS equipment, which performed real-time Fourier transforms in flight. Detailed postflight data processing was performed by the Ames IBM-360. Optical path stabilization was achieved by first reflecting the incident radiation from a roll-stabilized mirror. Roll compensation signals came from the aircraft inertial navigation system (INS).

Development. The polarizing interferometer (fig. 15) has been used for ground-based measurements since 1970, and improvements have continued as part of a normal development process. Although the equipment had never been flown before the Joint Mission, it had been used at a high-altitude Alpine location in 1974. Improvements made for the Joint Mission included the addition of a higher resolution mirror drive, a better temperature control for the detector cryostat (dewar), better regulated power supplies, and faster sampling in the data system. An IR-transmitting window port (fig. 16) with surface thermocouples was designed and fabricated at Ames as requested by the PI.

The experiment was designed for normal operation with continuous attention from one experimenter. In normal operation, a mirror travels the length of a long lead screw, the drive for which must be stopped before it jams. The lack of limit switches for this function presented scheduling difficulties for a single EO who had to operate two other experiments at the same time.

Figure 17 shows the experiment electronics mounted in a standard rack in the aircraft. ESTEC EMI requirements were followed in Level IV integration. However, the experimenters' unfamiliarity with the aircraft environment (in

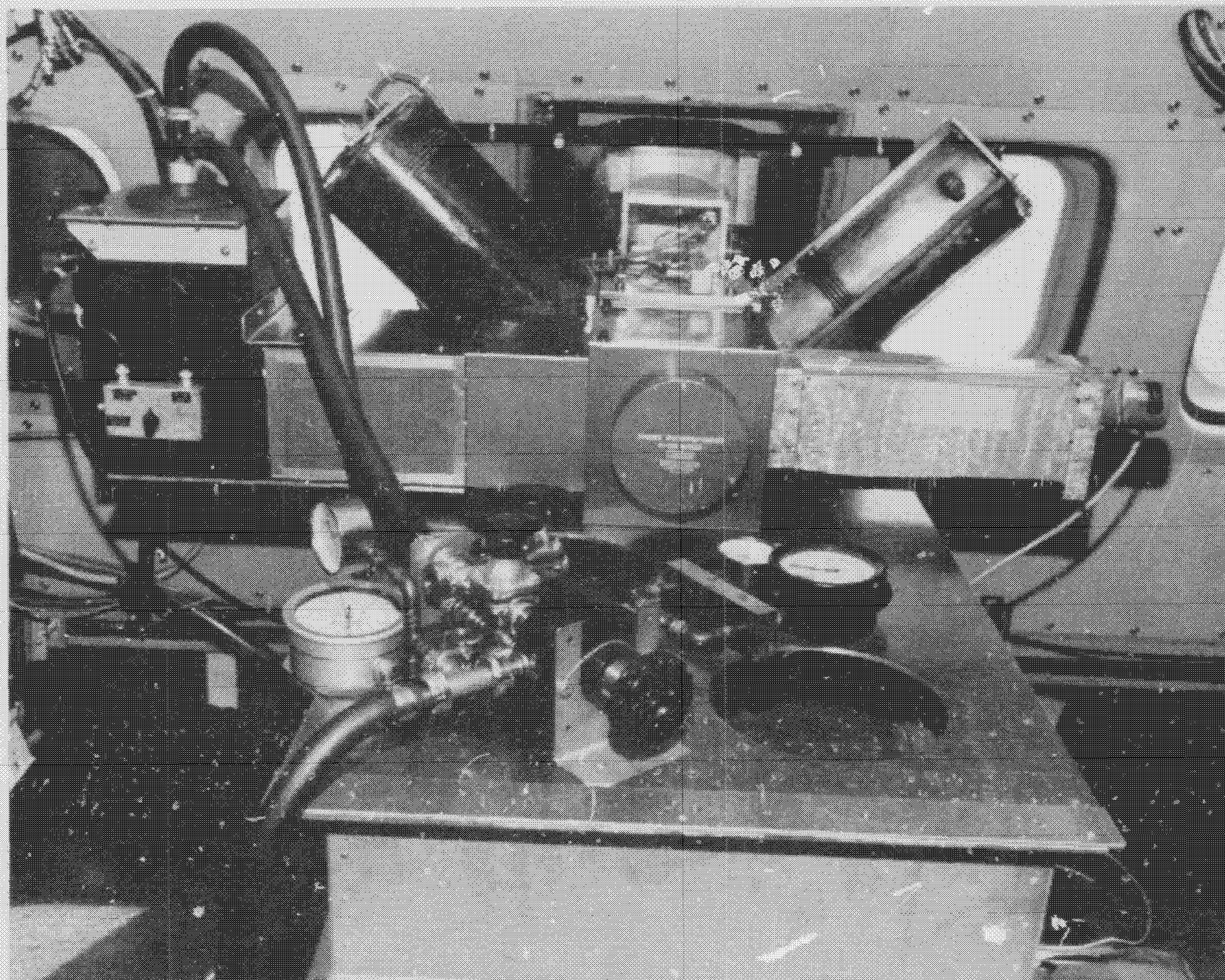


Figure 15.- QMC polarizing interferometer mounted on low-boy rack.

Figure 16.- IR window port, 1.9 cm × 17 cm diameter, UHMW polyethylene.

REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR

Figure 17.- QMC electronics in standard rack.

REPRODUCIBILITY OF THE
ORIGINAL PAGE IS POOR

an EMI sense) led to problems in flight with radiated interference from aircraft radio transmitters.

From the standpoint of ground-based science, this experiment was in a well-developed state at the time of selection. Modifications to meet flight and simulation constraints were completed before shipment to Ames. The two problems noted above were identified by the EO during the simulation period.

Experiment Readiness Review, March 25. At the time of the ERR, a sufficient selection of hardware items was on hand to assemble and complete the experiment package and Level IV integration was completed, with EMI isolation from the structure. However, several replacement components had not yet been delivered, including an improved black body and dewar. The PI planned to substitute these for existing units, which then would serve as backup equipment in the event of a failure. Similarly, a new drive system was to be installed at which time the complete experiment would be tested in the flight configuration. Earlier tests on a prototype experiment had shown EMI from commercial TV stations, but the problem was not expected to carry over into the flight experiment.

Data recording and analysis were not so well worked out. ADDAS would be the primary data logger, but arrangements had not been finalized for real-time or near-real-time, quick-look data reduction on ADDAS or comprehensive data reduction between flights. Software to prepare spectral plots on an IBM-360 had been contracted but not yet delivered. Components and some data subsystems had been tested.

Training of the European primary and backup EOs was in progress and would continue during operations at Ames, when the second backup EO from the U.S. would do all of his training. The EOs were in the process of making checklists and timelines. Procedures for maintenance and repair were well along, including tool selection and identification of support equipment.

University of Southampton (E3)

Scientific discipline:	Atmospheric physics
Scientific objective:	Observation of OH airglow clouds to determine wind velocities at altitudes between 85 and 110 km.
Participating organization:	University of Southampton (England)
Primary instrumentation:	Image Isocon TV camera system (65° window), 180° FOV camera (zenith window), photometer (65° window)
Observational bandwidth:	650-950 nm (near IR)

Description. This experiment was planned to measure motion of OH airglow clouds for a far greater period of time than can be achieved with sounding rocket chemical trails. Such information will aid in filling a large gap in present models of global winds.

The primary instrumentation consisted of an image Isocon TV camera, its control circuitry, and a recorder (fig. 18). The photocathode of the camera cuts off at about 950 nm, and a filter was used to cut off energy shorter than 650 nm. Integration times were generally on the order of 10 sec, although up to 2 min could be used. The integrated pictures were read out during a normal TV scan and recorded on a video recorder. A crystal-controlled 50-Hz power supply was provided to maintain European TV standards of 1/50 sec scan time and 625 lines. The TV camera data are being coordinated with the record from the all-sky camera, which utilizes IR film and exposures of 5 to 10 min.

Development. Initial ground use of this basic system was made in 1973 and 1974 on field trips to Norway. For the Joint Mission, substantial additions to existing equipment were necessary to implement mission guidelines, and to obtain reference measurements for field intensity and spatial distribution. The primary TV system was upgraded as follows. The camera control unit was modified to permit integration of the picture over several frames, and the video tape recorder was modified to handle data at the reduced frame rate. A small TV monitor allowed real-time evaluation of observations. A disc storage unit was added to the data-recording system to permit continuous viewing of the intermittent, slow-frame-rate images. A time-code generator was developed and added to the system to place time markers on the TV picture.

To permit viewing of the data with normal European TV standards, a 50-Hz power supply was provided. A special support was built to position the TV camera at a 65° elevation optical window in the aircraft. Auxiliary instruments, an all-sky camera and a photometer (fig. 19), were added to the experiment for spatial coordination and intensity calibration, respectively.

The prime EO for this experiment worked closely with the experimenters as a de facto member of their team, both at the home laboratory and at Ames, and thus contributed directly to the development and integration of the equipment. This experiment was not fully completed before shipment. During the integration period at Ames the TV camera support was strengthened to meet aircraft load factors, electronic circuitry was finished and details of Level IV integration were corrected to meet both safety regulations and EMI requirements. These sorts of activities during final integration are not uncommon in ASO programs, particularly when the experimenter has had no prior flight experience.

Because this team was unfamiliar with the design and operating constraints of the flight environment, extensive written communications were required with the Mission Manager and his staff during the laboratory development period. Even so, the problems encountered in adapting a ground-based experiment for airborne use (with added EMI requirements) were not completely resolved. Clearly, however, these problems could have been avoided or resolved early in the development period had an Ames design/airworthiness engineer visited the PI's laboratory.

Experiment Readiness Review, March 27. All hardware for the Southampton experiment was on hand at the ERR. The electronics were mounted in a standard CV-990 instrument rack with provisions for EMI isolation (fig. 20). The 150-lb camera was to be mounted on top of a rack using a two-position linkage (which

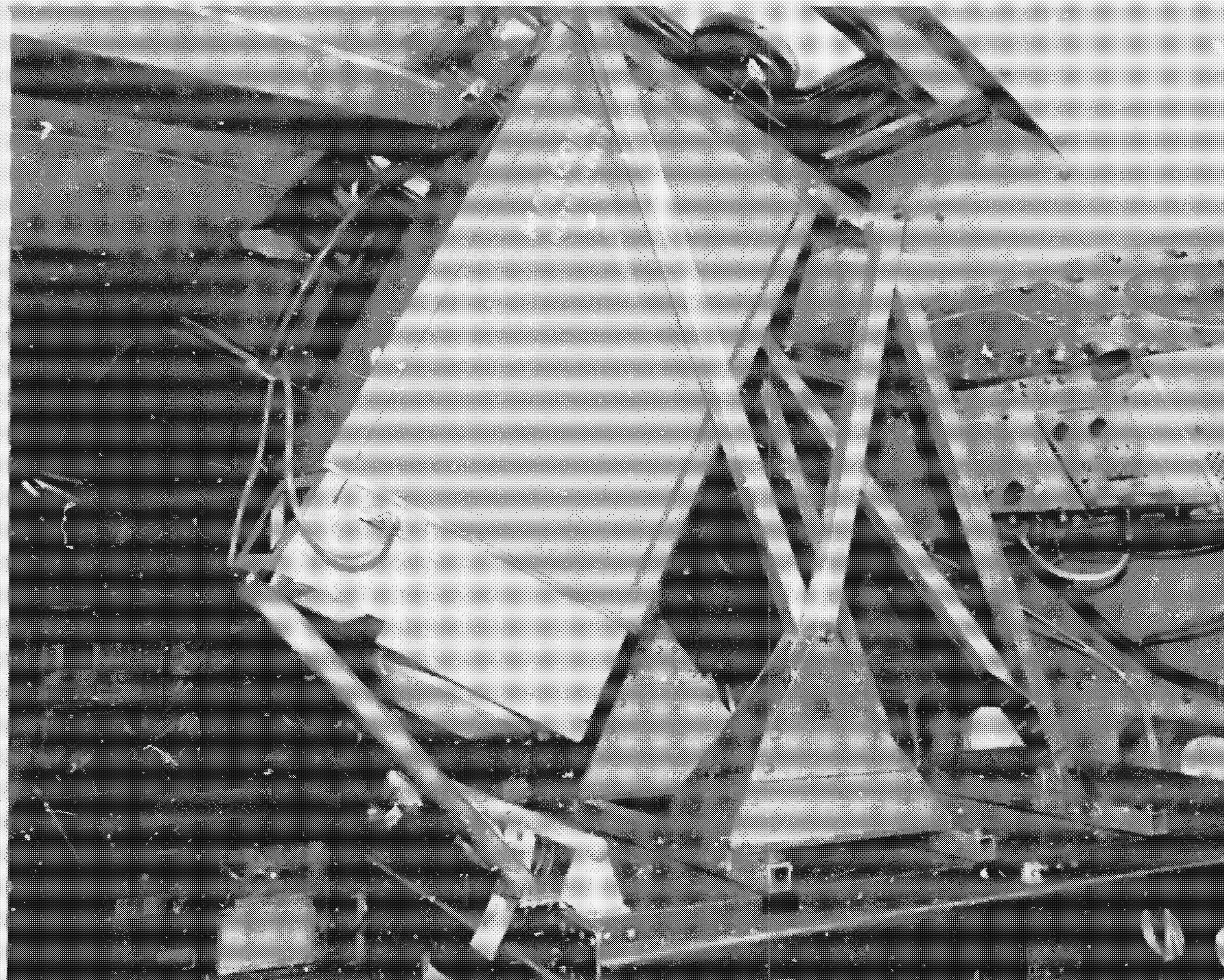


Figure 18.- Southampton TV camera on standard rack at 65° elevation window.

REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR

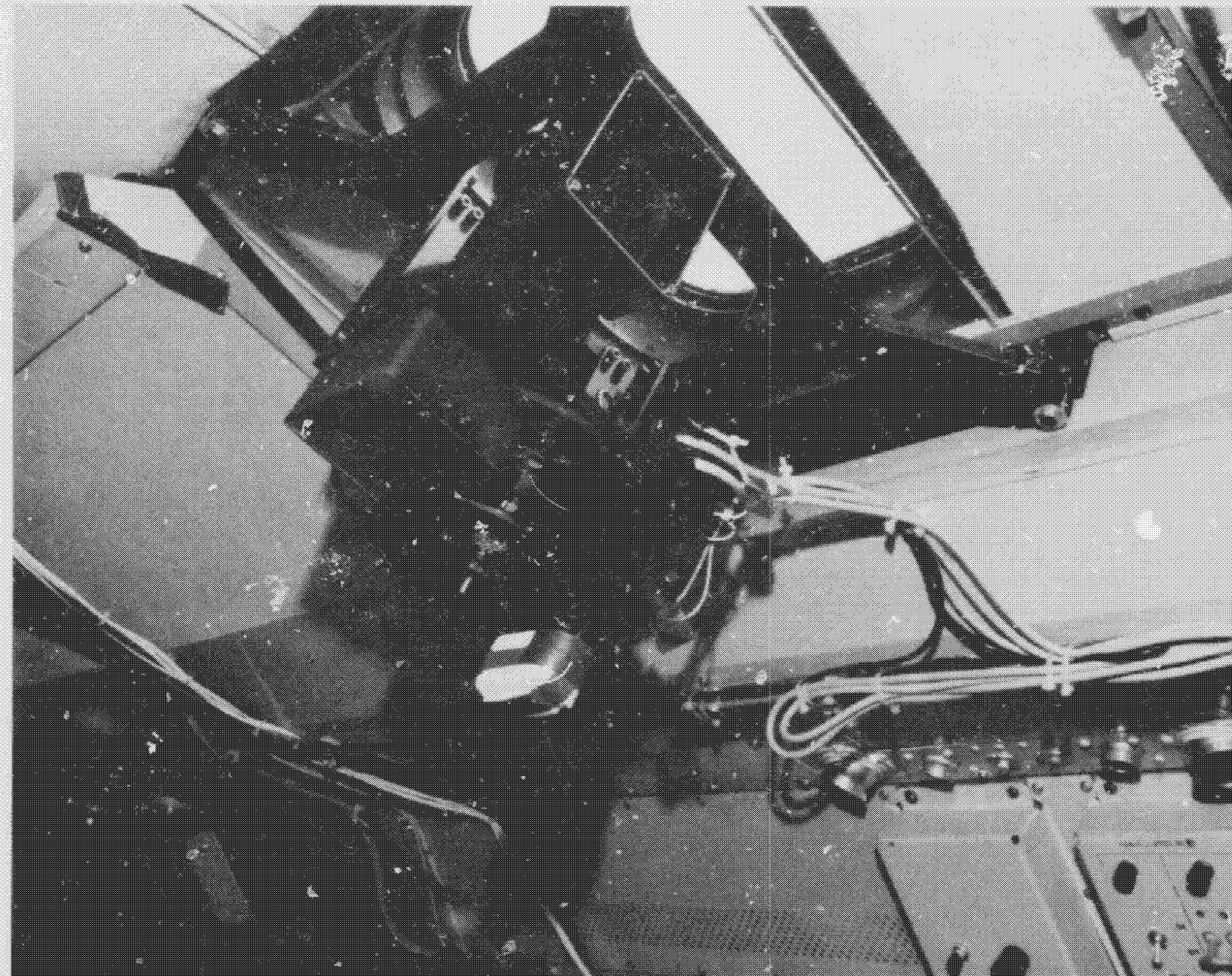


Figure 19.- Southampton photometer at 65° elevation window.

REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR

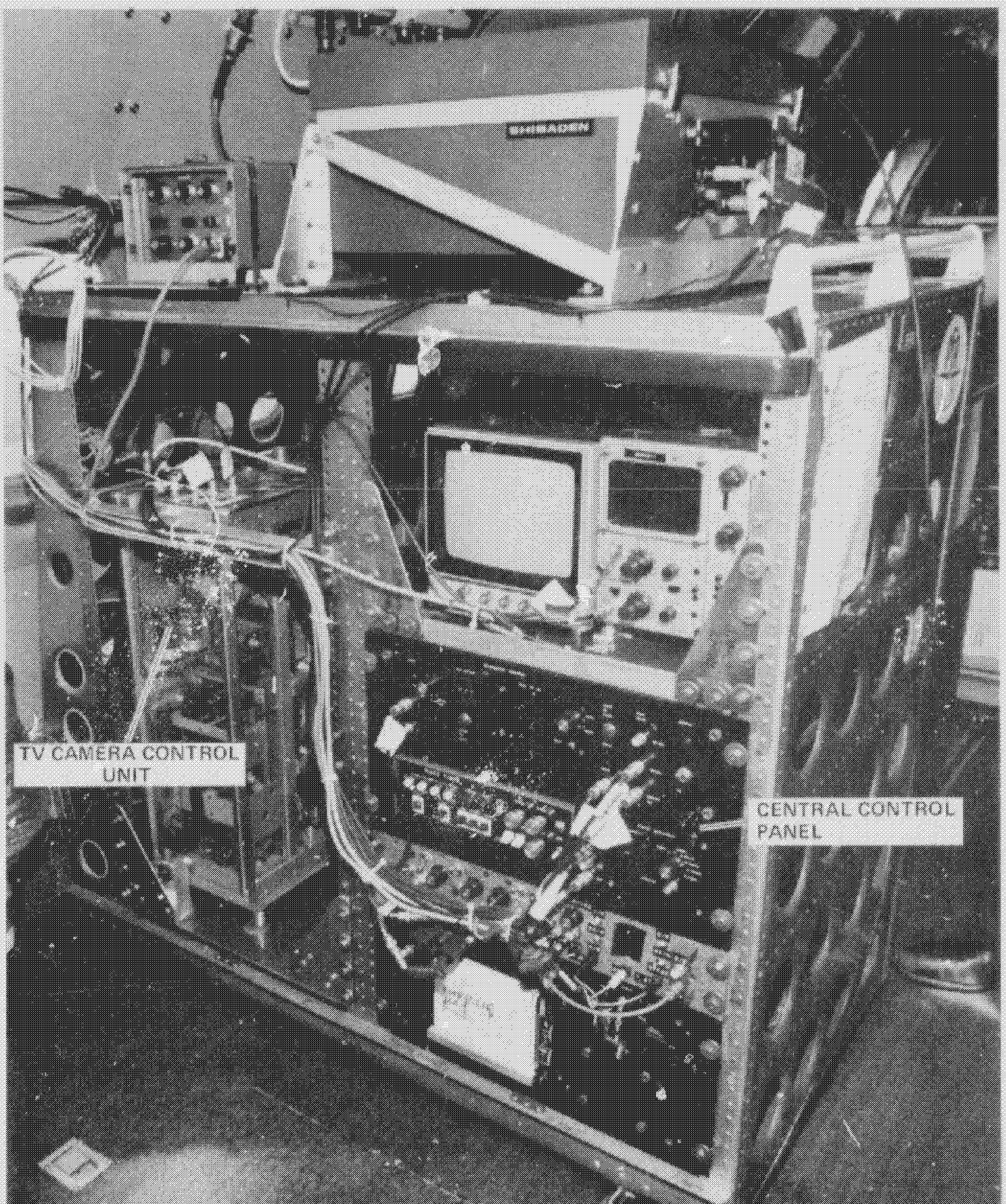


Figure 20.- Southampton electronics in standard rack.

existed as a drawing only) that would permit the unit to be lowered for convenient servicing. System tests had been performed on the TV system, but some of the electronics were being upgraded. The photometer was operating in a breadboard state, and the Nikon camera needed a simple mounting bracket. Experiment maintenance plans were outlined and support equipment identified.

All data logging was to be done with experimenter's recorders. A request was made for a special signal transmission line from the aircraft to the Mission Operations Center to be used after each simulation flight for copying the magnetic data tape. Other GFE support requirements were defined.

The prime EO had been involved in assembly of the experiment, which contributed to his understanding of the system. Training would continue with the PI and two EOs reviewing data obtained on earlier programs. The secondary EO from the United States would be trained at Ames. Final training was to be held on the aircraft. Reference material was being assembled. Although the EOs were preparing timelines and checklists, final procedures had to await the results from premission checkout flights.

Ames Research Center (US1)

Scientific discipline:	IR astronomy
Scientific objective:	Spectra of Venus and Late-type stars
Participating organization:	NASA-Ames Research Center
Primary instrumentation:	Filter-wedge spectrometer mounted on 30-cm Cassegrain telescope
Observational bandwidths:	3-6 μm

Description. The primary goal was to measure the absorption spectrum of sulfuric acid in the atmosphere of Venus. As a part of a general study, certain Late-type stars available during the mission were also observed.

The experiment comprised a detector and a filter-wedge spectrometer mounted integral with a dewar, along with associated electronic circuitry. Several variations of this experiment have been flown many times on the Ames Lear Jet with a similar IR telescope, and more recently on the Ames C-141 airborne observatory, to obtain similar measurements. The spectrum is swept by positioning different portions of a filter of varying thickness at the telescope focus. An indium antimonide detector was used, cooled to liquid nitrogen temperature. The experiment was mounted on the Meudon telescope in place of the Groningen photometer (fig. 21), but was not computer controlled. It was necessary to rebalance the telescope for operation of the Ames experiment. (See experiment E1 for telescope details.) Standard ac signal-processing equipment was supplied by the Ames group. Data were recorded on the ADDAS magnetic tape in digital format and on the GFE magnetic tape recorder in analog format. This experiment presented an interesting shared use of a major piece of equipment.

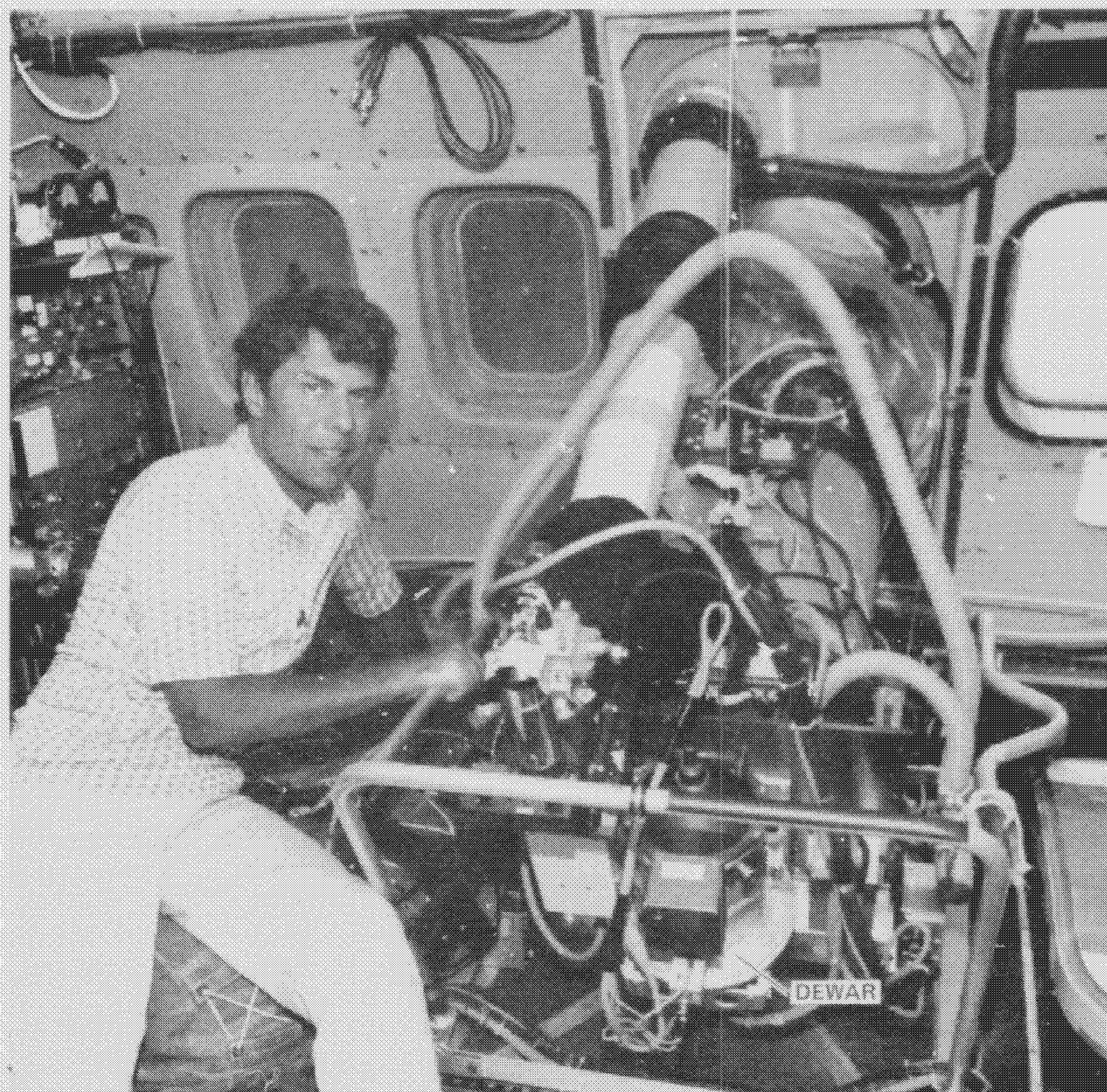


Figure 21.- Ames dewar on Meudon telescope, with EO making final checkout.

Development. From the science viewpoint, the experiment was well proven at the time of selection. The dewar was modified as necessary for mounting at the focal point of the Meudon telescope, in a time-share arrangement with the Groningen dewar. Both experiments used the same telescope controls, while signal electronics were entirely separate (fig. 22). New detector circuitry was constructed for the Joint Mission to permit a similar, previously scheduled experiment to fly in the C-141 in the same time period. Largely because of this schedule conflict, the new electronic equipment was not completed until well into the final integration. ESTEC EMI requests were implemented, however. The prime EO worked with the experimenter as an effective member of his team in the final development testing.

A mechanical interference between Ames dewar and the Meudon telescope mounting plate was found during final integration. The two research groups had addressed dewar interchange problems in earlier communication, but their solution was not properly expressed on the drawings furnished to the Ames PI, and additional machining was required on the Ames dewar during integration.

Experiment Readiness Review, April 18. The dewar/photometer was assembled and operating. An adapter plate had been fabricated and was to be fitted to the Meudon telescope on its arrival. All standard electronics subassemblies were available, but the interconnecting control panel had not been fabricated. A backup dewar/photometer and some backup electronics were to be available unless required for research on the Ames C-141 airborne observatory during the simulation period of the ASSESS mission. The analog output of the system was the basic data stream and would be recorded on the central GFE unit peripheral to the ADDAS system.

In March, the primary and secondary EOs had one day of training with similar electronics and the primary detector, using a reference body in the laboratory. Plans for subsequent training included familiarization with the Meudon telescope systems, refresher training on the experiment, and preparation of operating and troubleshooting checklists.

The ERR for this experiment did not serve the intended purpose: equipment was still being assembled, testing and calibration remained to be done, and Level IV integration had not begun, although the experimenter's plans for integration had been tentatively approved. It was apparent that scheduling had been keyed to the first flight date rather than to the ERR. In the resulting rush to complete the system, there was insufficient time to isolate and repair a microphonic condition within the dewar/detector unit. This problem was still being investigated by the prime EO during the simulation mission, and although some improvement was made, the malfunction was never eliminated.

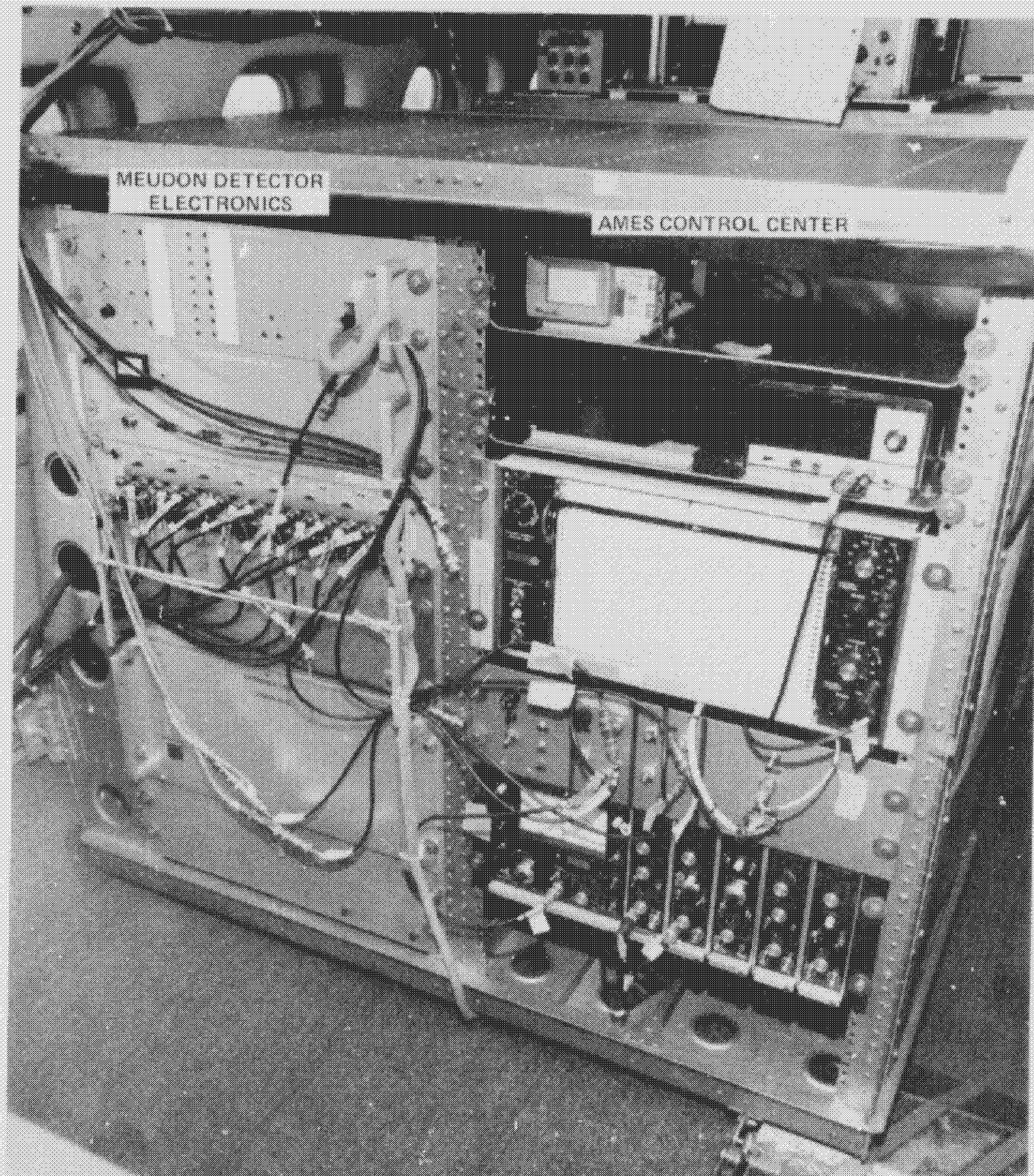


Figure 22.- Ames experiment control center in shared rack with Meudon detector electronics.

Jet Propulsion Laboratory,
University of Alaska, and
University of Colorado (US2)

Scientific disciplines:	Atmospheric physics and astronomy
Scientific objectives:	UV, visible, and near IR measurements of atmospheric transparency, solar flux, planetary atmospheres, and interstellar molecules
Participating organizations:	California Institute of Technology/JPL Geophysical Institute, University of Alaska University of Colorado
Primary instrumentation:	Tunable acousto-optical filter spectrometers (2) 1-m Ebert-Fastie spectrometer 12.5-cm Ebert-Fastie spectrometer
Observational bandwidths:	290-900 nm

Description. Each experiment in this group is described separately below.

Jet Propulsion Laboratory. The tunable acousto-optical filter (TAOF) is a new device capable of rapid scanning of the spectrum under electronic control. The incident radiation is polarized, and then enters a crystal in which a standing acoustic wave exists. Interaction between the acoustic wave and the radiation signal produces a wavelength-dependent rotation of the plane of polarization. With the introduction of a properly oriented output polarizer, the device becomes a tunable narrowband filter. The bandpass is covered by sweeping the acoustic frequency. Simultaneous modulation of the acoustic frequency permits use of ac signal-handling techniques. The signal is detected by a photomultiplier tube (PMT) operated in a photon-counting mode after which standard techniques are used in data handling. The data record was on the ADDAS magnetic tape.

Two TAOFs were used, one in the near-UV range and one in the visible range, each located at the focus of a 20-cm Schmidt telescope. The UV TAOF was used for observation of planetary atmospheres looking out of a 14° elevation window (fig. 23), and the visible TAOF was used to look upward through a 65° elevation window for sky measurements (fig. 24).

University of Alaska. The 1-m Ebert-Fastie instrument is a grating spectrometer, which operates from the UV through the visible spectrum (fig. 25). The observational bandwidth is set by mean grating position and selection of various cams that fix sweep range. The detector - a thermoelectrically cooled photomultiplier - and associated electronics were operated in a photon-counting mode. Data from the detector were fed to a minicomputer, which could store, sum, and display complete spectra. A backup record was made on the ADDAS magnetic tape. Detailed examination of a portion of a spectrum could also be initiated by the operator.

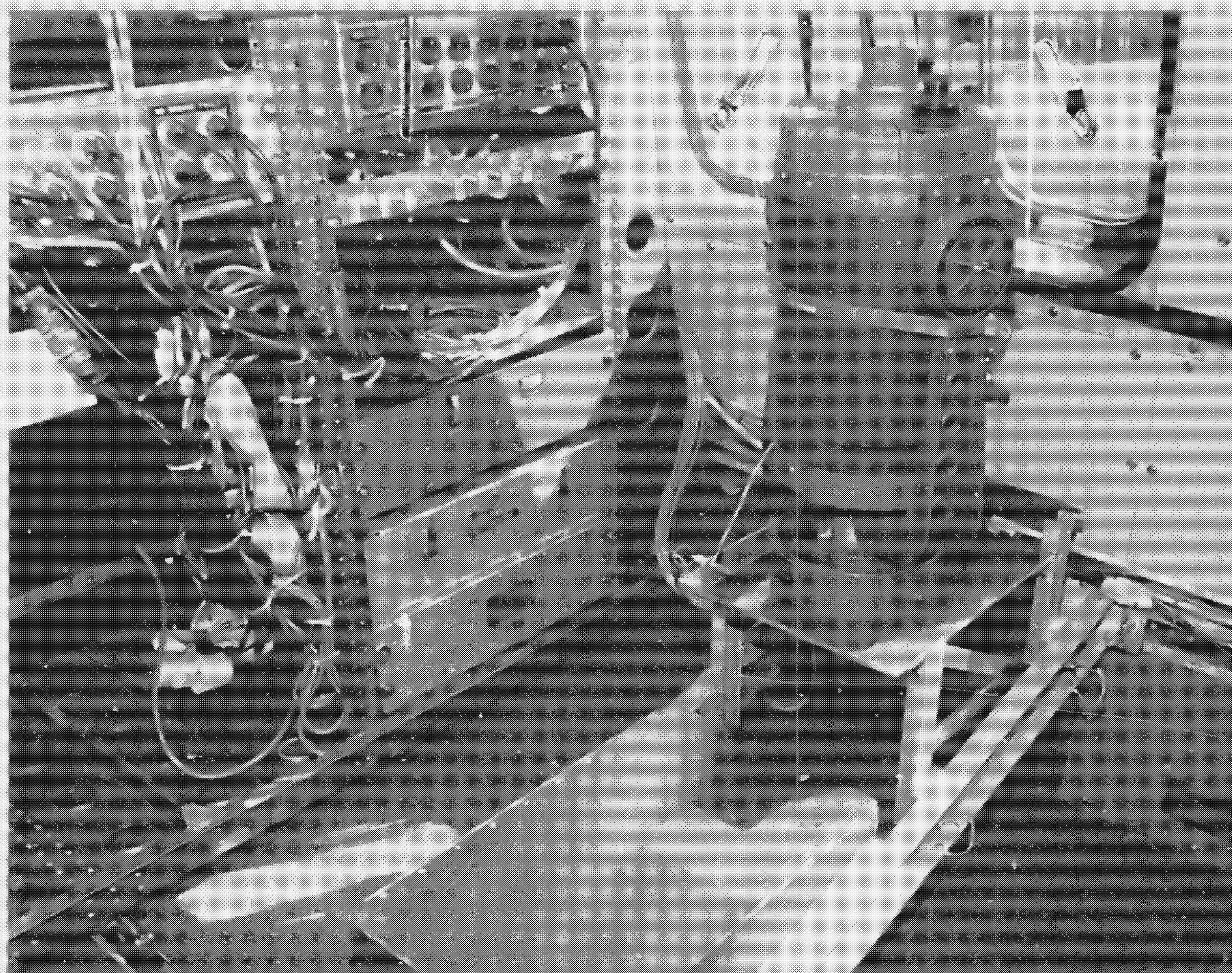


Figure 23.- JPL 20-cm telescope mounted at 14° optical window, in stowed position for takeoff, TAOF not shown.

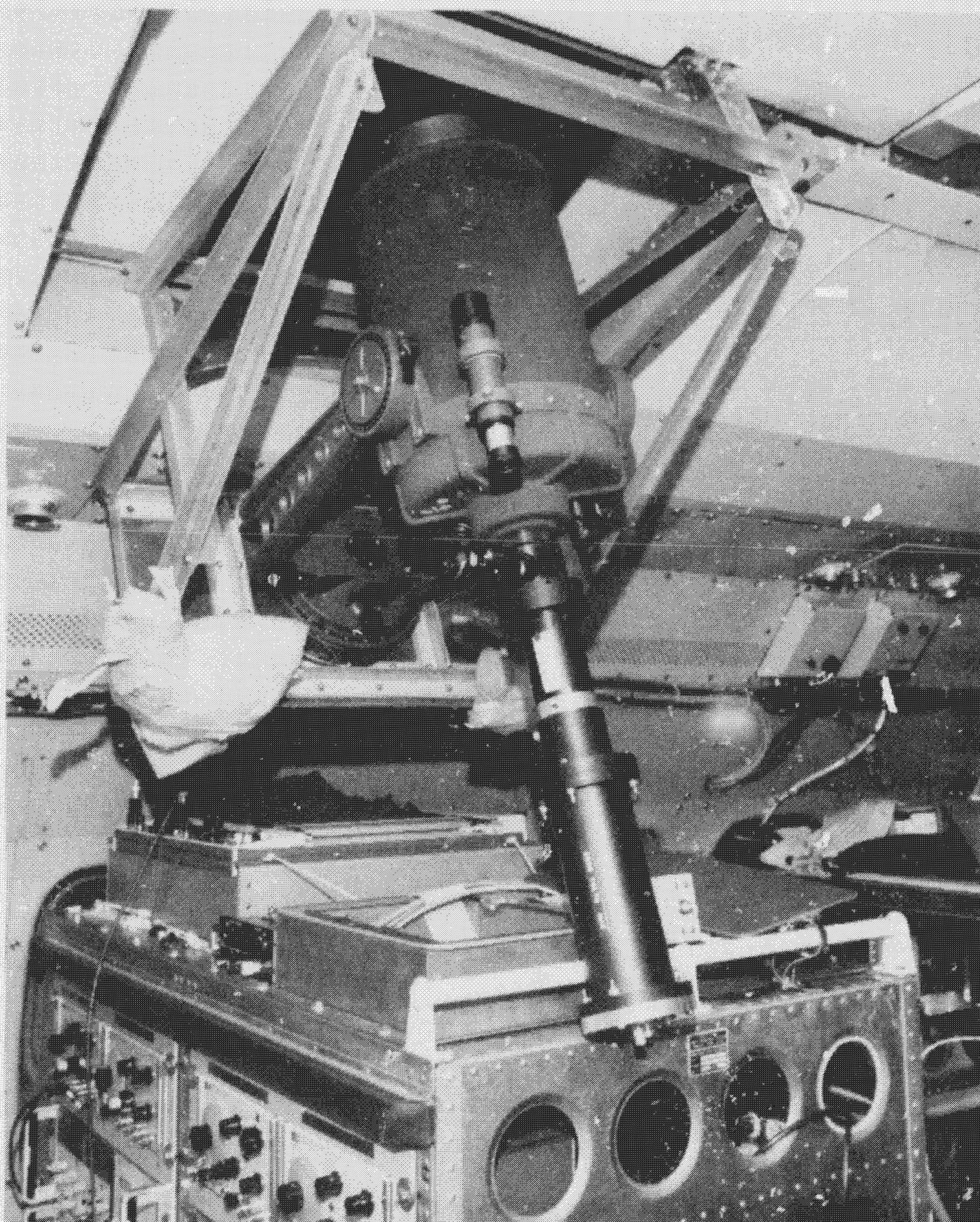


Figure 24.- JPL 20-cm telescope with TAOF attached, at 67° optical window.

REPRODUCIBILITY OF THE
ORIGINAL PAGE IS POOR

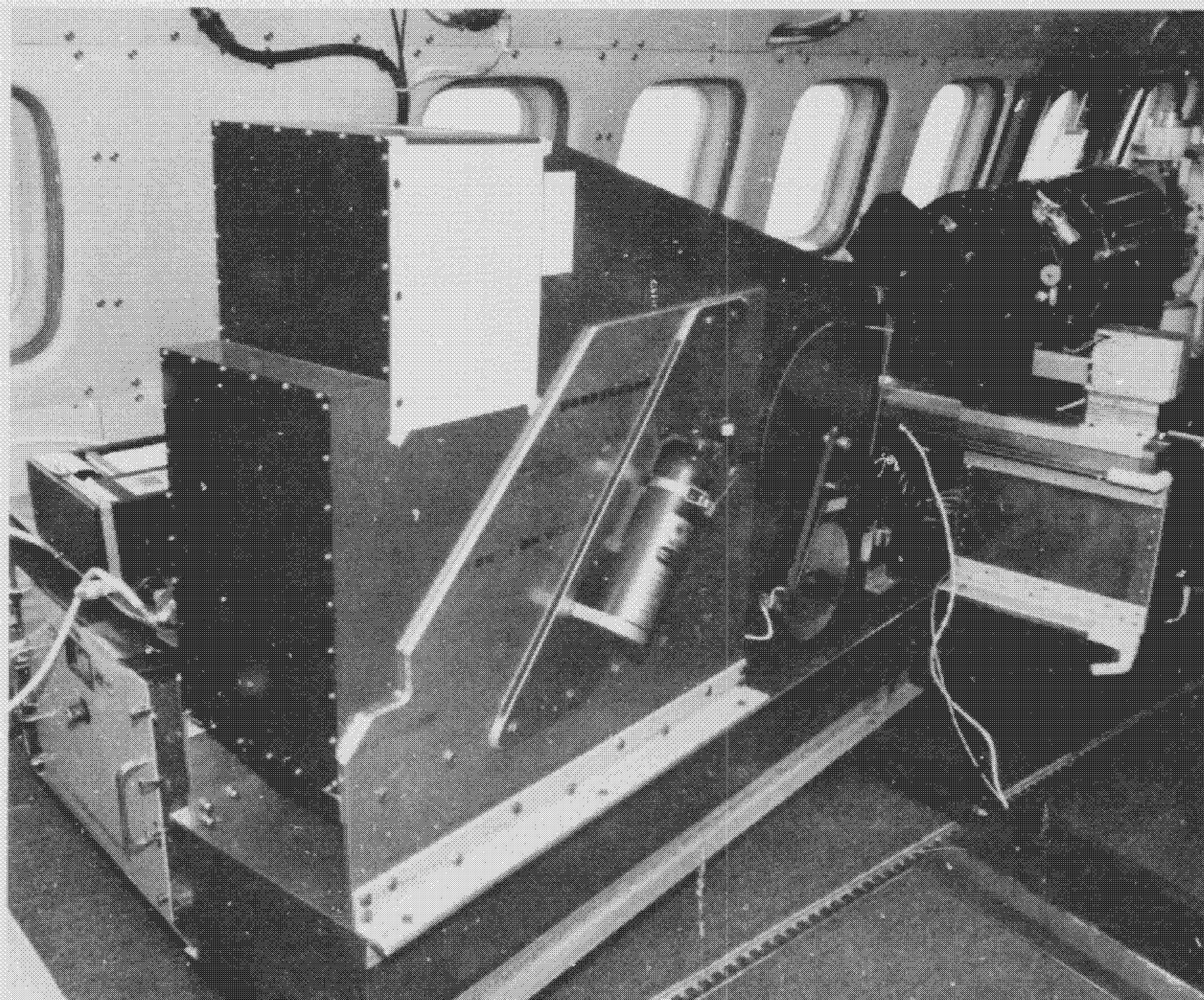


Figure 25.- Alaska spectrometer mounted on optical beam in CV-990.

A 35-cm telescope was used to focus the desired image on the input slit of the spectrometer. Two devices were used simultaneously to position the optical path: a gyrostabilized mirror corrected for motions about the center of gravity of the aircraft, and a star tracker adjusted the telescope secondary to keep the image centered on the spectrometer's slit.

The experiment was designed to obtain spectra of specific objects such as the planet Venus, as well as spectra of skyglow. In viewing an astronomical object, the spectrometer looked at the target out of a 14° window through the telescope and gyrostabilized mirror (fig. 26). In the skyglow mode, the telescope and mirror were not used, and the spectrometer looked out of a 65° window using a plane mirror.

University of Colorado. The 12.5-cm Ebert-Fas[illegible]ectrometer is the prototype of a Pioneer Venus Orbiter instrument. Its operation was similar to that of the 1-m instrument except that data in the visible and UV channels were taken simultaneously. Also, because of its initial purpose, the spectrometer was designed for remote control by a minicomputer having sum and display capabilities similar to those of the Alaska computer. Data were recorded in digital form with a dual-cassette tape recorder.

Initially, this spectrometer was installed to time share the 35-cm Alaska telescope and stabilized mirror (fig. 27). This arrangement proved unsatisfactory, however, because of the low optical quality of the telescope and the different imaging requirements of the two instruments. Therefore, after the simulation period, the Colorado instrument was moved so that it could time share the UV TAOF Schmidt telescope and stabilized mirror (fig. 28).

Development. The three experiments described above were to be combined into a single integrated experiment with the investigator from JPL as the PI. Each portion was developed separately, however, and coordination among the investigators proved inadequate. Few attempts were made to coordinate controls or to simplify operation for the EO handling this equipment.

Jet Propulsion Laboratory. At the time of selection for the mission, the JPL TAOF experiment existed only on paper, but it had sufficient potential in combination with the other two elements of this group to justify its inclusion. The proposed instruments were advanced state-of-the-art devices whose measurements, in part, could be compared with results from the more conventional spectrometers. The PI had participated in one previous ASO flight, and the primary EO had an extensive record in airborne astronomy. However, EO participation was delayed 4 months while a replacement was found for the originally selected EO.

Early development was severely handicapped by late delivery of one TAOF unit by the manufacturer. The TAOF first entered the market in late 1974, and the visible-light unit was delivered to JPL in January 1975. The corresponding UV unit was not delivered until May, after final integration had started.

The visible-light TAOF was tested in the JPL laboratories and at the JPL observatory at Table Mountain, California, during January-March 1975.

Figure 26.- Alaska 35-cm telescope and gyrostabilized mirror mounted on optical beam in CV-990.

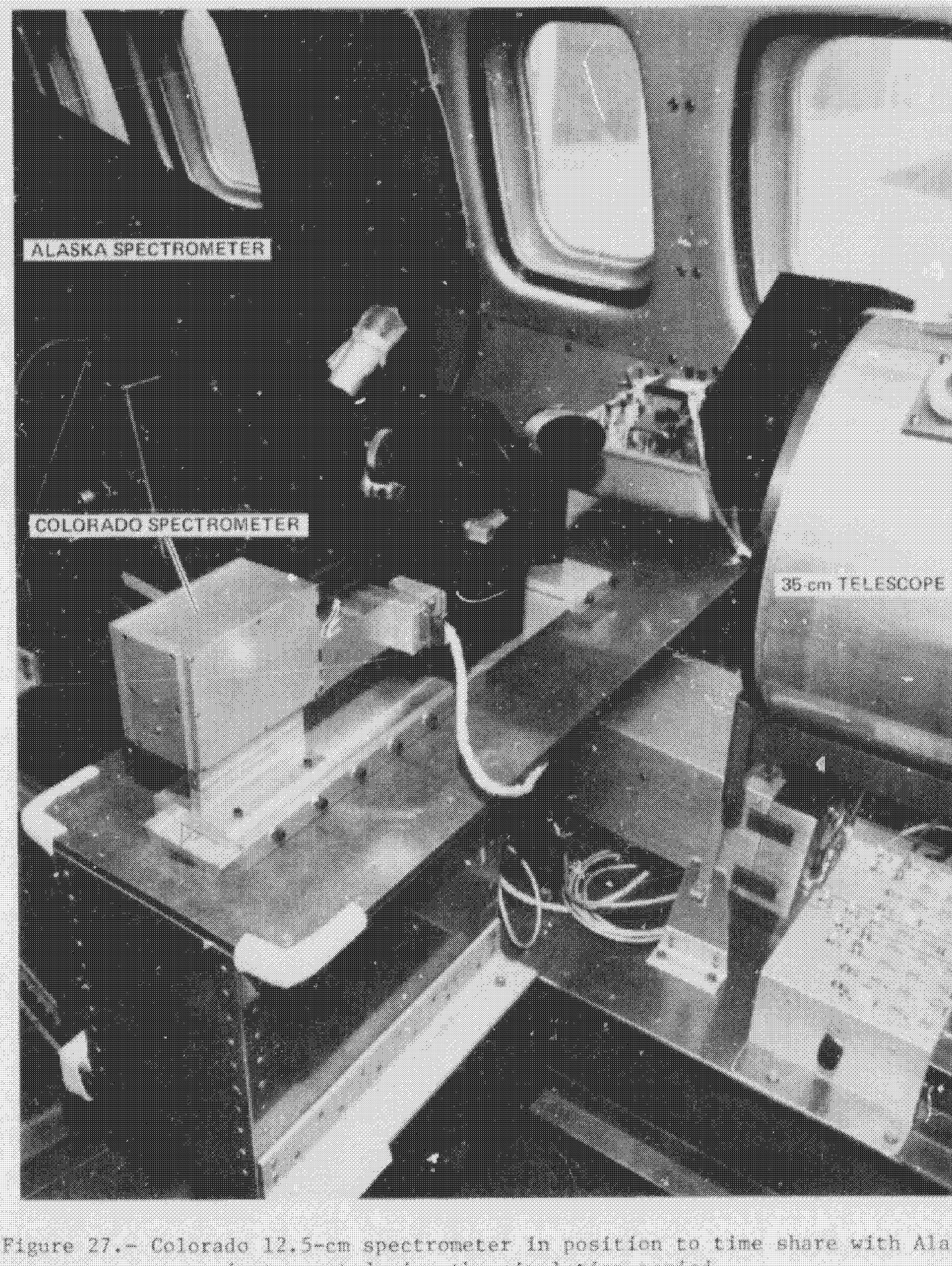


Figure 27.- Colorado 12.5-cm spectrometer in position to time share with Alaska instrument during the simulation period.

REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR

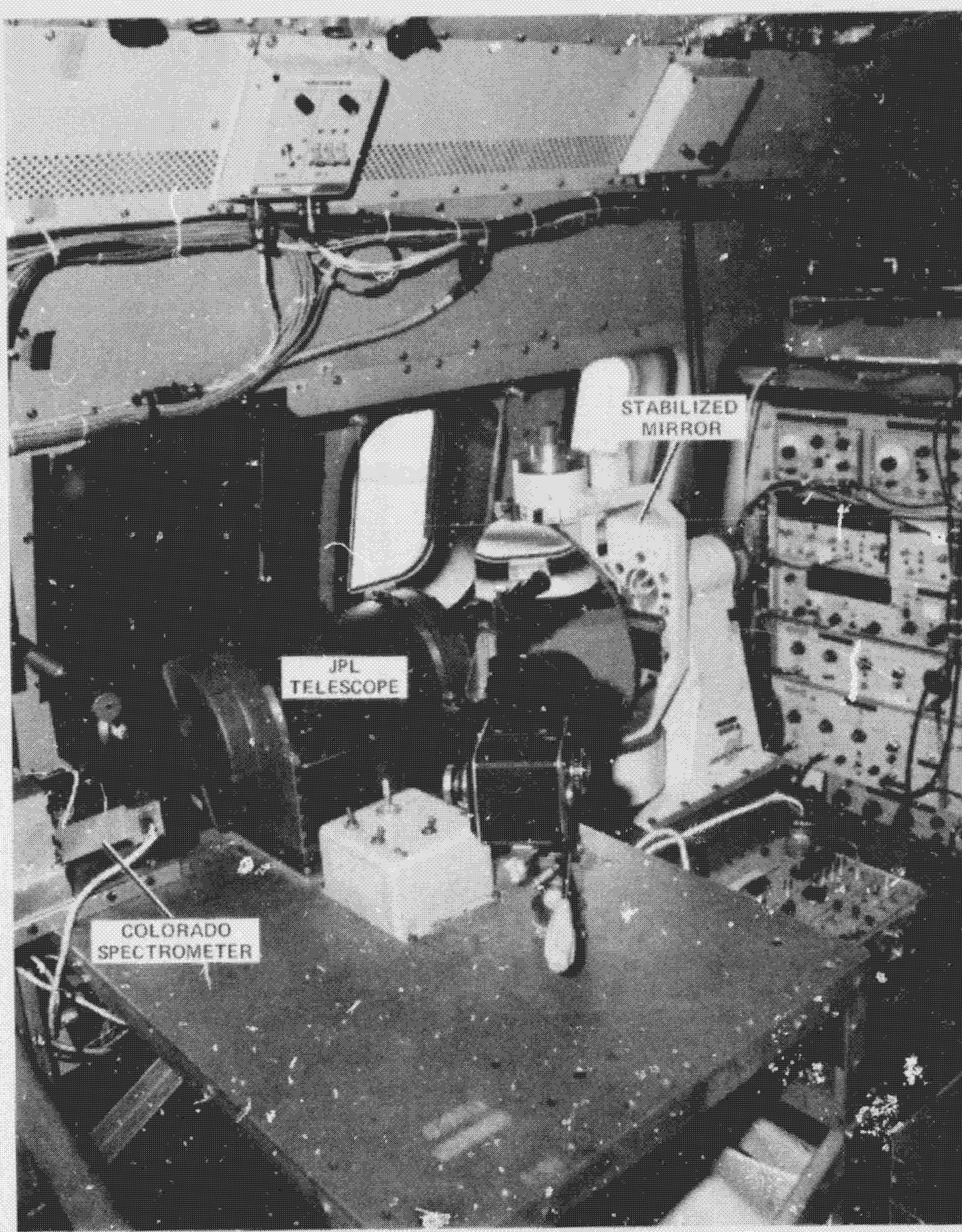


Figure 28.- Colorado spectrometer mounted to share stabilized mirror and JPL telescope during the postsimulation period.

Conventional analog circuitry, largely commercial laboratory equipment, was used during this portion of the development testing. Development and construction of the associated optical equipment proceeded at the same time, but satisfactory operation was not achieved during the initial test period. In April, the electronic equipment was redesigned to digital circuitry, and the equipment was tested again at the McDonald Observatory in Texas. It was this second configuration that was installed on the aircraft. The UV TAOF was delivered to the PI too late to do any but the most elementary checkout and testing, although the electronic circuitry was ready and waiting. Plans for ADDAS control of one TAOF were dropped as program delays mounted.

The experiment concept called for each TAOF to be attached to a 20-cm Schmidt telescope. Neither had been tested as a complete unit prior to integration at Ames, however. Originally, the telescope holding the UV unit was to be manually tracked on astronomical objects such as the planet Venus. The manual tracking procedure was immediately found to be impractical on the aircraft, and a gyrostabilized mirror was added following the simulation period. ESTEC EMI requests were not implemented for this experiment, although the PI agreed with their purpose and value, particularly when EMI became a serious problem for his experiment. Level IV integration, scheduled to take place before shipment, was largely implemented at Ames (fig. 29). At the request of the PI, ASO provided all special equipment supports for the experiment.

<u>University of Alaska</u>. When selected, the Alaska experiment was a proven scientific concept. For the Joint Mission, it was to be implemented with more sensitive instruments and equipped with an automated data-processing system to permit operation by a single EO. The basic instrument was a new 1-m spectrometer scheduled for delivery in the fall of 1974. The telescope necessary for light collection and imaging was a borrowed unit, promised early in 1975 but not available for setup in the laboratory until just before shipment to Ames. The required stabilized mirror was furnished by the ASO. The experimenters were basically familiar with this class of instrumentation, having operated similar but smaller instruments for several years. Their experience also included flights on the CV-990.

The new data-handling system, which included a minicomputer, was developed for the experiment in the early spring of 1975. Because of the delay with the telescope and the complexity of software development for the data system, final optical alignment and checkout of the entire system was deferred until assembly on the aircraft mounting structure at Ames during the integration period. The equipment was sent to Ames a week early to permit fabrication of special mounting brackets and to allow extra time for final alignment. By mutual agreement, ASO provided all special supports for the experiment.

The prime (replacement) EO for this experiment was quite familiar with the spectrometer, having participated earlier in its devel[illegible] as a consultant for the manufacturer. He worked with the experiment[illegible]al checkout periods at Alaska and at Ames. Had he joined the te[illegible] of development, however, his participation would have been even [illegible]al.

With the short time available for final developmen[illegible]periment, little attention was given to EMI compatibility or to hu[illegible]eering for

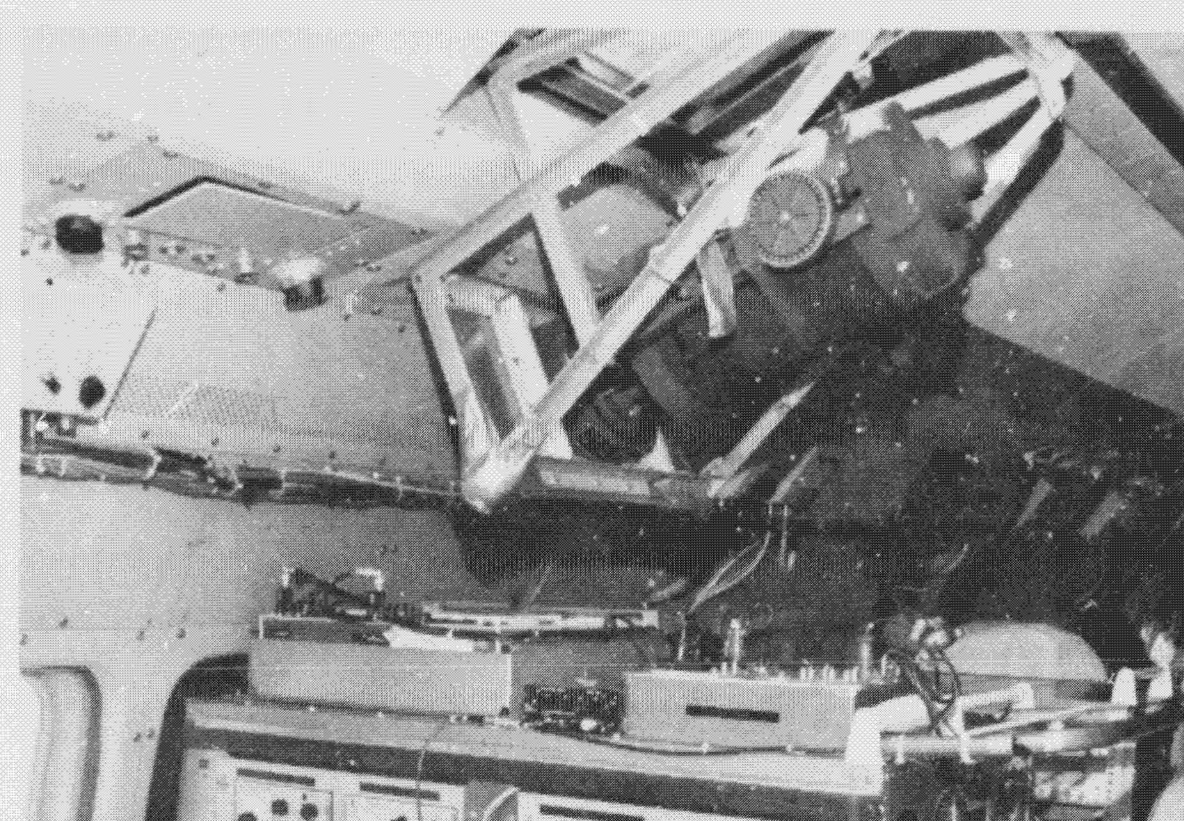


Figure 29.- JPL control center with electronics mounted in standard rack.

REPRODUCIBILITY OF THE
ORIGINAL PAGE IS POOR

ease of operation by an EO. In fact, some switches were located in out-of-the-way places that were awkward to reach and easy to forget. The equipment was not a proven, operational system at the time of the ERR. However, there appeared to be no serious, unresolved problems, and Level IV planning was complete. The final installation of Alaska's electronic systems is illustrated in figures 30 and 31. For whatever reason - perhaps previous ASO experience was an influence - the PIs scheduled their full system verification tests during the integration period at Ames. This decision was not the best, in view of the delay in coordination among the three experiments in this group. Time was short, and certain problems with optics and the data system were not completely solved before the simulation began. In fact, data system problems persisted throughout the simulation period.

University of Colorado. The 12.5-cm spectrometer was initially developed for the Pioneer Venus Orbiter. Work on the prototype instrument began in July 1973, before the scheduled starting date for Pioneer, to permit observations on the newly discovered Comet Kohoutek. However, even with an accelerated schedule, construction and testing were not completed until June 1974, well after the comet perihelion. As part of the development program of the Pioneer instrument, the prototype spectrometer was subjected to operational, vibrational, and environmental testing. Tests involving operation of the entire experiment were carried out (starting in March 1974) with the data-handling system employed during the present mission. Between June and the start of active preparation for this mission in late 1974, the experiment was used successfully several times on mountain-based telescopes.

Preparation for the present mission consisted only of some additional operational testing and the construction of supports required for mating the spectrometer to JPL or Alaska optical systems. As noted, no effort was made to coordinate controls with the other two experiments in this group, or to provide specific EMI compatibility with other experiments or aircraft systems. Level IV integration was planned in advance but not implemented until arrival at Ames (fig. 32).

Plans for functional integration of the Alaska/Colorado experiments were far from complete at the beginning of the final integration period. Arrangements for beam interception to permit time-sharing the 35-cm telescope with Alaska were completed before the checkout flight began (fig. 27), but the arrangement was not satisfactory. The 35-cm telescope was of rather poor optical quality, and it was optically matched to the Alaska spectrometer, not the 12.5-cm Colorado spectrometer. This unfortunate mismatch could not be remedied in time for the simulation period and detracted from the EO's performance of his research assignment.

During the simulation period, operation of the Colorado experiment was simplified to the extent of using only the simplest computer programs - that is, those which summed spectra and recorded the results on magnetic tape. Many variations were available that also performed various aspects of spectral analysis. The EOs were not requested to use the latter. As noted, the Colorado experiment was reconfigured following the simulation period to time share one of the JPL 20-cm telescopes with the UV TAOF. Much improved data were obtained with this arrangement

Figure 30.- Control center of Alaska experiment.

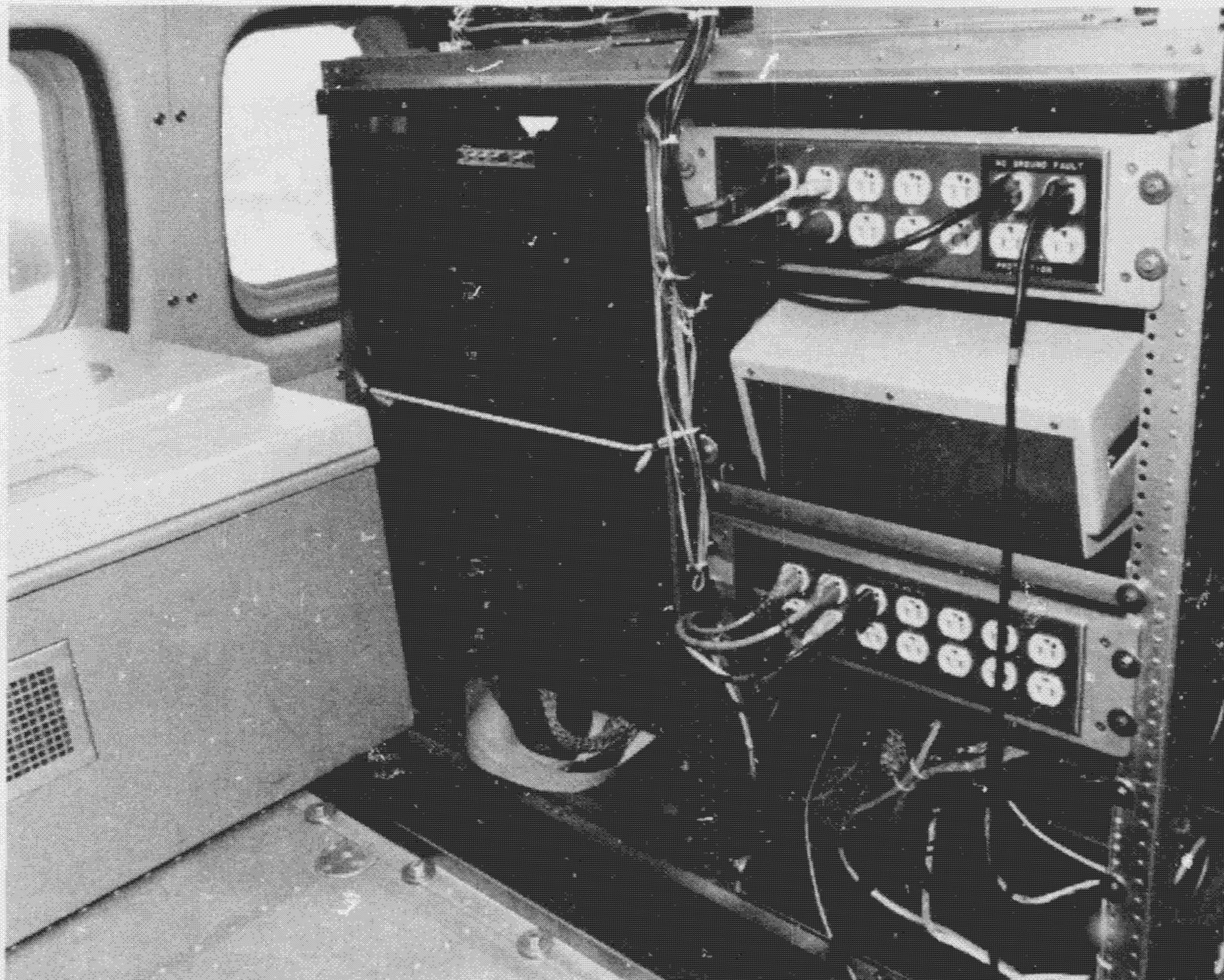


Figure 31.- Rear view of Alaska rack.

REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR

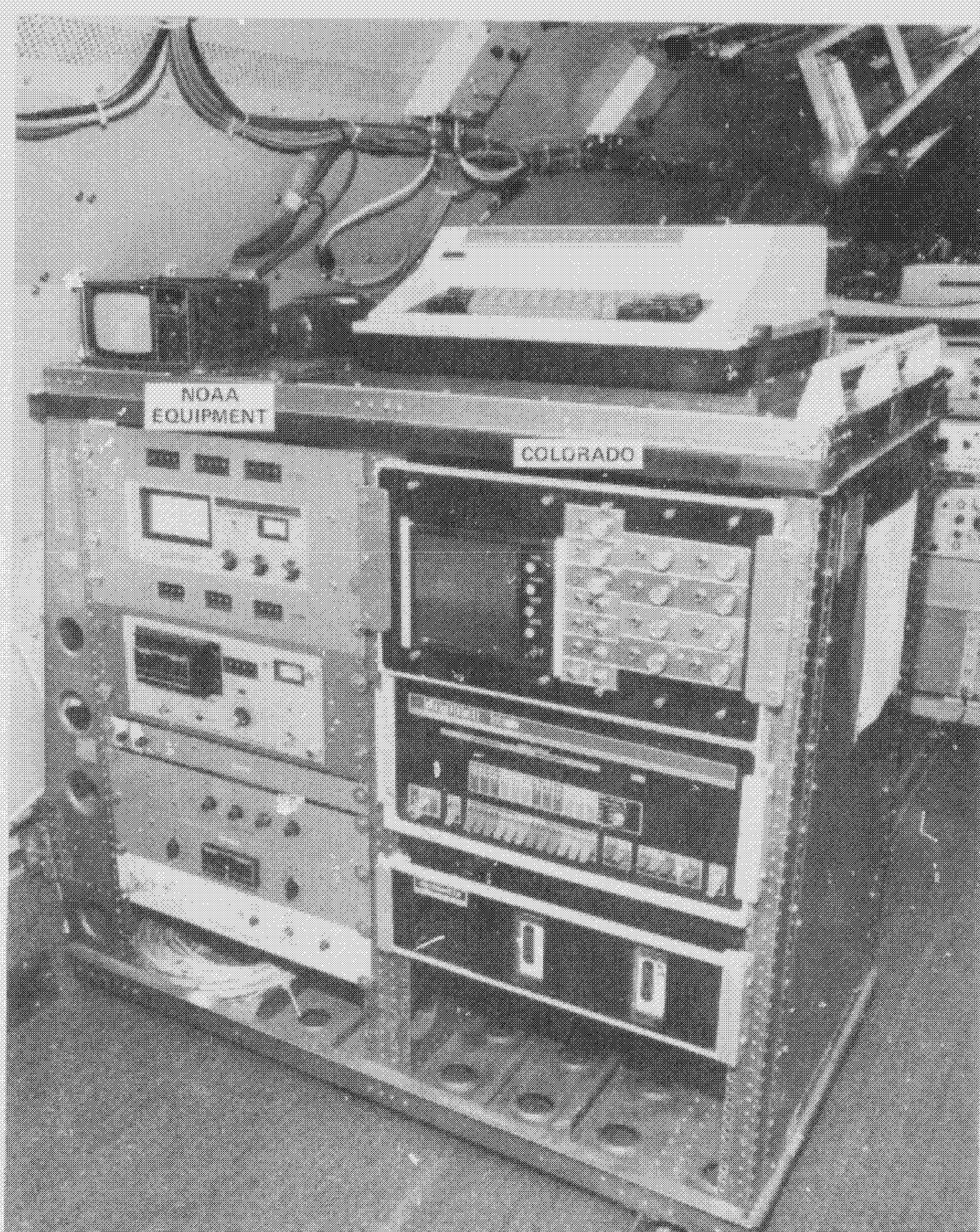


Figure 32.- Control center for Colorado experiment in inboard bay of standard rack; NOAA ancillary equipment for atmospheric water vapor measurements in outboard bay.

Experiment Readiness Review, April 8. The JPL/Alaska/Colorado group of experiments showed many loose ends at the ERR. Most of the custom mounting hardware was being designed and built at Ames, and was in various stages of completion. Mating, assembly, and alignment of optical instruments was deferred until final integration. Level IV integration was in progress at JPL, using standard CV-990 racks. Alaska and Colorado had ASO approval of Level IV plans but would do the work at Ames.

JPL had completed laboratory tests of one spectrometer, and the first of a two-part test series at ground-based observatories using prototype electronics. Final tests of the completed flight system were scheduled for mid-April. The second spectrometer had been damaged in fabrication and delivery was promised in late April. The associated electronics were tested and ready. No spare components were available; some small parts would be furnished, but reliance on the primary equipment was mandatory.

Alaska had completed testing on nearly all components and subsystems, and had been operating the spectrometer/computer complex in a real-time mode for several months. Software development was in the final checkout stage. Preparations to control the GFE stabilized mirror with signals from a star-tracker unit were only beginning. No problems were anticipated during mechanical/optical assembly at Ames. Critical parts and components were backed by spares.

The Colorado experiment was thoroughly tested, and except for final integration with the Alaskan optical system, it was ready for flight. As part of another development program, the spectrometer had been tested for environmental effects including EMI. No backup equipment was available, except for small standard parts.

Government-furnished equipment (GFE) in support of the three experiments was finalized during the ERR. For data handling, Colorado was self-contained; Alaska was to use the ADDAS for backup recording only; and JPL regarded ADDAS as the primary recorder and planned for inflight processing, printout, and hard-copy graphic display. The latter functions had not been finalized or programmed by the ERR date.

Both the primary EC, and his European backup, had a week or so of training at both JPL and Alaska but no exposure to the Colorado experiment. The second backup EO did not plan to train before arrival at Ames.

Preparation of operational procedures and checklists was started during EO training, but could not be finalized since neither experiment was fully assembled and operating. Operating timelines were not even attempted. Beyond this, the lack of coordination between the PI and his co-investigators at separate geographical locations meant that training was entirely at the individual level, with no consideration for interactions in time or workload with the companion systems assigned to the EO.

REPRODUCIBILITY OF THE

University of New Mexico (US3)

Scientific discipline: Atmospheric physics

Scientific objective: Photography of infrared airglow

Participating organization: University of New Mexico

Primary instrumentation: 35-mm camera with IR image intensifier, 16-mm camera with IR image intensifier for time-lapse photography, IR photometer for calibration

Observational bandwidths: 650-900 nm

Description. This experiment studied infrared OH airglow clouds near the horizon, using wideband photography of large areas of the sky and narrowband photometry of the center of the area photographed. The two cameras were equipped with image-intensifier tubes (ITs) to permit exposure times of the order of seconds, using wide bandpass filters covering 700-900 nm The 16-mm camera made time-lapse exposures, producing motion pictures of the changing airglow structures. The 35-mm camera made one photo per minute.

The red-sensitive photometer recorded airglow intensities through eight filters: three narrowband filters centered between airglow bands to record background, one opaque filter, and one wide bandpass filter identical to those used on the cameras for absolute calibration. A Geneva drive continuously changed the filters with a 20-sec dwell time on each.

The experiment was initially operated from the left side of the aircraft, although arrangements had been made to use windows on either side. After the simulation period, the 35-mm camera and photometer (on the right side of fig. 33) were operated from the left or right side of the aircraft as dictated by data-collecting possibilities. All data were recorded on film and a strip chart recorder, and the ADDAS system was not used except to obtain a time record of the aircraft track.

Development. The New Mexico experimenters had extensive ground experience in photographic recording of atmospheric OH clouds. However, to take best advantage of the platform provided by the CV-990, new and more extensive equipment was assembled for this mission. ESTEC requests for EMI compatibility were implemented during assembly. By mutual agreement, some special instrument supports were built by the PI and some by ASO. Level IV integration was completed after arrival at Ames.

During the fall of 1974, numerous items were ordered, the flight instruments were designed, and preliminary experiments were performed with a two-stage electrostatically focused IT. Earlier it had been found that a three-stage IT would permit the airglow to be recorded with a 1/15-sec exposure using a broadband filter (700-900 nm). However, this tube had very large pincushion distortion and a nonuniform photocathode. With the two-stage IT, it was hoped that photos of the individual bands could be obtained through 10-nm interference filters, in exposures of about 1 sec. However, a compromise

Figure 33.- New Mexico experiment mounted on low-boy rack, left side of aircraft.

PRODUCIBILITY OF THE
ORIGINAL PAGE IS POOR

was necessary, and a broadband filter to permit a 1-sec exposure was used to minimize the effects of smearing due to aircraft roll. Earlier experiments with a selected one-stage IT showed it did not significantly reduce the 5-min exposure time required by regular high-speed infrared film and a fast camera, and it was therefore not satisfactory.

Several tests of various transfer lens systems, to image the IT output screen onto the recording camera film, revealed that (1) no closeup lens system, or single lens with extension tubes, will operate well at 1:1 imaging; (2) two 35-mm camera lenses face-to-face make a good transfer lens, but the field of view is too restricted; and (3) oscilloscope recording lenses designed for 1:1 imaging offer the best results for this work.

Modifications were made to the original equipment to facilitate operation by an EO who could give only part-time attention to the equipment. A timer was added to control camera exposure, and the photometer filter wheel was motorized. Following these modifications, the EO had only to load film, start up the equipment, and then monitor it periodically.

Although much of the equipment for this experiment was new for the mission, the scientific method was proven, and since the basic instrumentation was relatively straightforward, the experiment was considered well developed at the time of selection. The experimenters had never flown their equipment before, but this lack of experience did not cause any problems.

Experiment Readiness Review, March 21. The PI stated that nearly all experiment hardware items were on hand at the time of the ERR. Some spares had not come in. Full system tests were in progress, but poor observing conditions in the field had delayed their completion. Level IV integration of the experiment was defined (for implementation at Ames) and was acceptable to ASO, but there were detailed arrangements yet to be resolved such as black cloth light shields and procedures for shifting the photometer and still camera from port to starboard. Little attention was paid to data systems; the experiment was self-contained and components were operational.

Regarding EO training there were no outstanding problems except that one secondary operator (from Europe) had not received any instruction. Procedural documents were being prepared. The indicated level of effort appeared compatible with time-shared operation, in the opinion of the primary EO.

Management Effectiveness

In retrospect, it appears that the Mission Manager's role and his authority to require conformance with the guidelines and schedules of experiment development were not clearly defined or broadly enough applied. For the most part, his management approach followed normal ASO practice for conglomerate payloads, where interaction between PIs is minimal at the hardware state - that is, each PI develops a separate experiment and does any required operator training. For the Joint Mission, however, equipment changes to improve EO performance were left largely to decisions of the individual PI,

despite their probable wider influence, and since EO responsibilities crossed experiment lines, coordination among PIs was necessary to implement centralized controls. In this important area, management control was virtually nonexistent.

In practice, the ERR milestone was a reasonably effective control of experiment development. Its significance was lessened, however, by delegation of this Mission Manager responsibility to others (in Europe) and use of a telephone rather than an on-site review (in the United States). Thus, most of the experiments were not fully completed during the development phase, and changes were still being made during the final integration period at Ames.

Finally, failure to meet the set completion date influenced EO training plans, again across experiment lines. In none of these areas was the management influence adequate. EO timelines were designed to fit individual experiments, control functions were not centralized except on some individual experiments, and delayed completion of most experiments made adequate training during the integration period at Ames more difficult.

EXPERIMENT OPERATOR SELECTION AND TRAINING

Selection Parameters

As a result of time limitations and the fact that the Spacelab Payload Specialist selection procedures had not been developed, the MPG decided not to exercise a formal EO selection process such as is anticipated for Spacelab. Instead, the EOs were selected directly by the MPG in accordance with the following general parameters:

1. Two U.S. and two European EOs would be selected

2. Selection of European EOs would be an ESA responsibility, performed under the direction of the European member of the MPG

3. Selection of U.S. EOs would be made directly by a designated subpanel of the MPG

4. EO candidates must be individuals capable of conducting normal research programs planned by the PIs - that is, no significant reductions in experiment complexity or scope should be required to accommodate EO capabilities.

The spectrum of background experience of the four selected EOs was deliberately chosen to permit study of the amount of training and background experience required to become a satisfactory EO. The European EOs had been selected by September 1974. U.S. EOs were selected at the same time, but encountered schedule conflicts with ongoing workloads that prevented active participation. One withdrew from the program in November and was replaced in February 1975. The other (a scientist/astronaut) got approval to share responsibility, in the early stages of training, with an associate who later replaced him as EO for

the entire mission. In both cases the replacement EOs had roughly the same amount of background experience as those originally selected.

Experiment Operator Backgrounds

Experiment operator A,[1] ESA EO, was an astrophysicist specializing in infrared astronomy, with valuable prior experience in airborne research as an experimenter on the French-sponsored Concorde Eclipse flight in 1973. His experience in ground-based astronomy included two assignments in the United States. At the time of selection, he was a visiting scientist at ESTEC, on leave from his position as Lecturer in his home university.

Operator B, ESA EO, was a graduate student in plasma physics. His academic work was related to the atmospheric physics experiments on this mission, and he was associated with the University of Southampton through a cooperative arrangement between that organization and his home university.

Operator C, NASA EO, also a physicist, had been associated with the Kitt Peak Observatory. He had also participated in two auroral expeditions on the Ames CV-990, and was associated with the original development of the type of 1-m spectrometer used in the JPL/Alaska experiment. At the time of selection, he was associated with The Johns Hopkins University and the University of Maryland as research scientist and associate professor, respectively.

Operator D, NASA EO, was a scientist/astronaut from the NASA Johnson Space Center. He was the only EO on the Joint Mission with extensive general training in the operation of scientific instruments for experiments sponsored by others. He had previous experience in airborne research, including flights aboard the Ames Lear Jet. He also served as Science Advisor for a major NASA space program.

Role of the Principal Investigator

Previous experience with EO training in the ASSESS program indicated that an acceptable level of proficiency in experiment operation can be accomplished by direct PI/EO interaction with little outside supervision (refs. 9, 10). Accordingly, the same approach was followed for this mission. The PIs were requested by the MPG to devise training plans and schedules jointly with the EOs, and to define the criteria they would use to evaluate progress in training and overall EO performance. This information was to be sent to the Mission Manager by mid-December for his use in monitoring the training program. Formal management control over the training program was limited to two status reviews by the Mission Manager, one planned for late March about one month prior to shipment and the second at the end of the training period late in May.

This approach to operator training was a logical extension of the basic ASO management philosophy, wherein the responsibility for implementing an experiment rests with the PI, and was deliberately chosen to evaluate its effectiveness in the context of time-shared operation of multiple experiments.

---

[1]Names have been omitted to conform with provisions of the U.S. Privacy Act of 1974.

At the very least, this was the direct way to ensure that training experience would be individually tailored to match EO capability with operational requirements. However, in some cases, PI planning of a coordinated EO training program, including provision for EO participation early in the mission and for sufficient hands-on training, was not adequate to ensure smooth operation of experiments with effective interaction among the EOs.

Experiment Operator Responsibilities

These assignments constituted the basic framework and dictated the main requirements for PI planning of EO training programs - both in content and in procedures. The Spacelab life support system is designed to support a maximum of three people continuously. Therefore, the Joint Mission was designed for equipment operation by only three EOs on any given flight. The fourth EO was off duty. Each experiment operator was assigned prime responsibility for an experiment, or group of experiments, and secondary (backup) responsibility for additional experiments (table 4). The primary and secondary experiment responsibilities were chosen to ensure sufficient cross training that any three EOs could operate the payload on a given flight. This arrangement was designed to provide an effective one-man backup for a three-man crew. To allow maximum possible study of training adequacy, EO assignments were rotated during the mission to include primary and secondary experiment operation.

TABLE 4.- EXPERIMENT OPERATOR ASSIGNMENTS

Experiment group	Responsible EO: Primary[1]	Responsible EO: Secondary[2]
Queen Mary College		Operator C
University of Southampton	Operator B	
University of New Mexico		Operator A
Meudon Observatory and University of Groningen	Operator A	Operator B[3]
Ames Research Center	Operator D	Operator C[3]
Jet Propulsion Laboratory		Operator D
University of Alaska	Operator C	
University of Colorado		Operator B

[1]Primary responsibility included the capability to maintain and repair equipment if necessary.

[2]Secondary responsibility was limited, in principle, to normal operation and data interpretation.

[3]Assignment made, limited training effected, but never operated in this capacity.

The EOs were required to operate experiments that were basically laboratory equipment. Few attempts had been made to reduce the number of switches, controls, and adjustments that each EO had to understand and operate correctly. Each EO had to contend with a hundred or more such individual devices on the two groups of three experiments each. The number of controls on the Meudon/Groningen (or Ames) experiment was slightly smaller, but the experiment also entailed a demanding tracking operation. The numerical complexity of operations

required of the EOs is indicated by table 5, which summarizes the numbers of switches and indicators associated with each experiment. The experience of the EOs and their ability to handle all required tasks during the mission are discussed under MISSION RESULTS.

TABLE 5.- NUMBERS OF SWITCHES AND INDICATORS FOR EXPERIMENT OPERATION

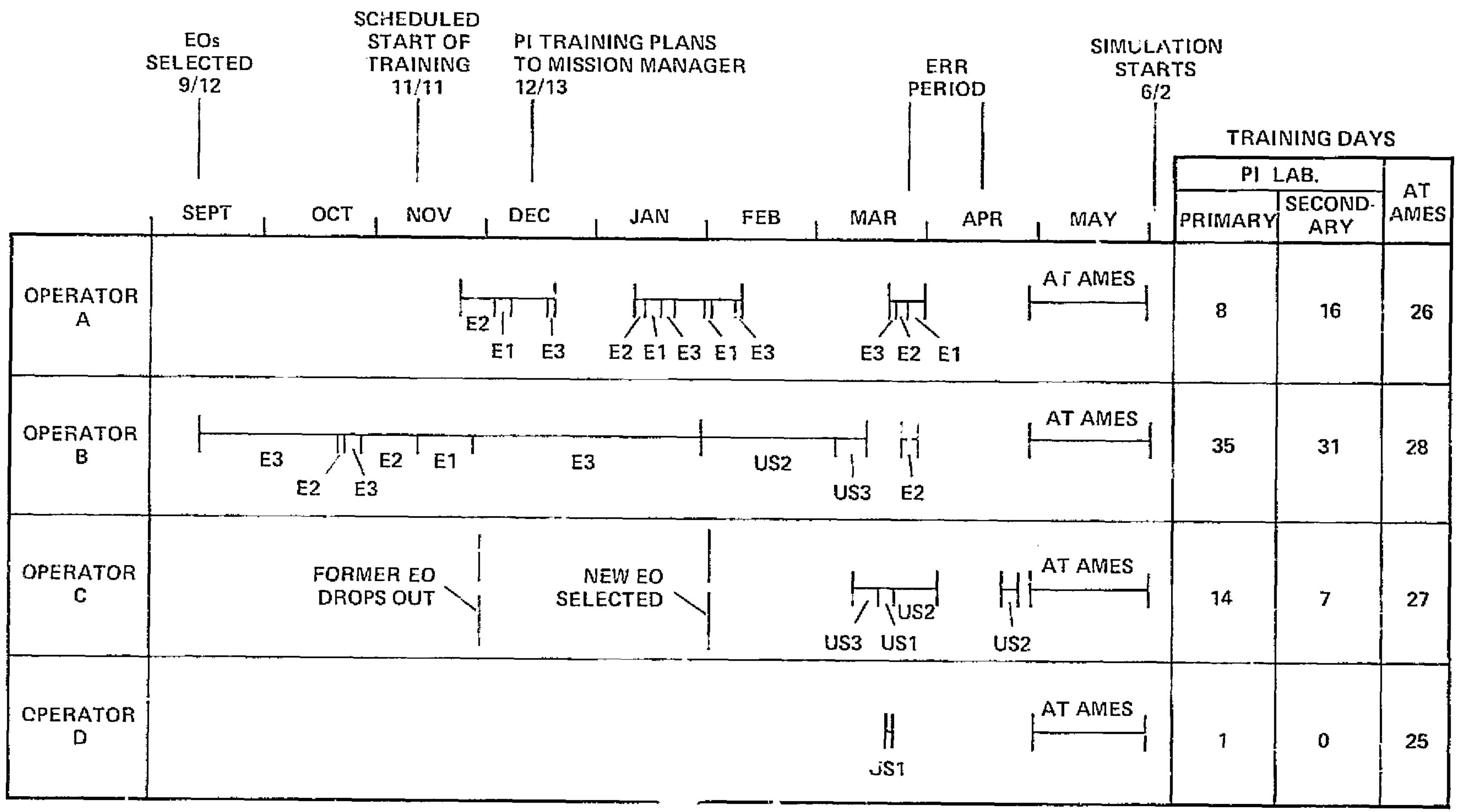
Experiment		Cryogenics	Number of switches and adjustments	Number of indicators (all types)	Computer terminal	Tape recorder
Queen Mary	Grouped for one EO	Yes	25	56	Yes	No
Southampton		No	46	11	No	Yes
New Mexico		No	15	5	No	No
Meudon/Groningen		Yes	60	35	Yes	Yes (3)
Ames		Yes	45	30	No	Yes
JPL	Grouped for one EO	No	65	15	No	Yes
Alaska		No	41	10	Yes	No
Colorado		No	20	3	Yes	No

The Training Process

The start of EO training at the PIs' laboratories was scheduled on the MPG milestone chart for mid-November, two months after selection, to allow time for necessary arrangements between the participants as well as for U.S. experimenters (also selected in mid-September) to organize their own programs. For the European experimenters, however, this meant a full six months of development with no direct EO participation. As it turned out, there was a wide variation in training schedules. One EO started in September, a second in late November, and the other two in mid-March 1975 (fig. 34). Thus, the early formative stages of all experiment development went on from 4 to 7 months without direct EO participation, although there was some prior communication in all cases.

Ground-Based Training

Days of active training during the experiment development period varied from 1 to 66; not all days were fully utilized, but the EO was on location. Most of the time was spent assimilating background information through the study of equipment manuals, discussion with the PI and his team, and demonstrations of equipment operation. Much training was related to components and subassemblies because the experiment was not yet complete. Later in the period there were limited opportunities to operate primary or prototype equipment. In general, the EOs were not satisfied with their experience in the laboratory, and expressed two opinions: first, training was too informal and not well enough organized to be really effective; and second, there was not enough hands-on training to develop any real operational confidence. With some exceptions, the overall experience was not of the expected quality and depth.



*ADDITIONAL 40 DAYS SPENT AS DE-FACTO CO-INVESTIGATOR IN THE DEVELOPMENT OF E3.

Figure 34.- EO training calendar.

On the other hand, it should be recognized that formal training at the system level before the Ames period was not possible because of the lack of ground support equipment (GSE). For cost reasons GSE was omitted from the program, and it was considered that ground and flight checkout with the aircraft would be an effective substitute.

The integration and checkout period at Ames (25 to 28 days) was the most critical part of the entire training process, and for Operators A, C, and especially D, it was the principal training period. This was the time for the EOs to become familiar with the integrated experiment, to develop operational procedures for combined experiments, and to become proficient in all aspects of operation and servicing.

During experiment integration and checkout, the EOs assisted the PIs in actual equipment assembly and testing, and in the preparation of instructions for EO operation of the experiments. The instructions listed the various procedures necessary for the proper operation of each experiment and also included some fallback procedures in case of problems or unavailability of some desired observational objects.

The first opportunity for the EOs to operate individual experiments in the flight configuration was during the final two weeks prior to the Spacelab simulation week. Daytime activities were supplemented by observational sessions at night with the aircraft on the ground in a dark location during which representative targets were tracked and data were recorded. Such sessions were conducted on five separate nights for about four hours each night.

Inflight Training

The final phase of training was analogous to integrated mission simulation in manned spaceflight programs. One training flight was scheduled for each EO, who would operate his prime experiment (or group of experiments) for four to five hours; no inflight training was scheduled on secondary experiments. The guidelines for EO training were as follows: during the first half of the flight, the operator would be responsible to start up and operate the experiment without direct assistance from the PI. The PI would be in the back of the airplane, available only via the intercom. For the remainder of the flight, the PI would be available for direct "hands-on" assistance if requested by the EO, but the EO would still be the primary operator.

The first checkout flight was for PIs to verify experiment operation. EO flight training was scheduled so that the primary Ames EO was trained on flight two and the others on their primary experiments on flight three. It should be noted that several experiments were still not in good operating condition by the time of these flights. In particular, the Meudon/Groningen and University of Alaska experiments had significant troubles. Aerodynamic buffeting of the telescope in its open cavity still plagued the first, while the latter lacked a good boresight and had problems with its integrated computer system.

Because of these problems and the overall small amount of prior hands-on experience, the EO training guidelines were not closely followed during either flight. On flight two, the Ames EO was not involved at all during equipment turn-on and the first data leg. When he did become involved, he had the

assistance of both the Meudon and Ames PIs throughout his period of activity. During flight three, there were several calls for direct PI assistance during the first half of the flight, and after due consideration, these were allowed. In addition, a PI was called forward to visually assess a situation he would have to attend to later, and the Meudon/Groningen EO received the assistance of a Meudon electronics technician throughout the whole flight to manually augment the stabilization system against cavity disturbances that prevented proper guiding. Finally, the latter half of the third flight became primarily a training session in which the PIs operated their experiments and taught by example.

The EOs were unanimously of the opinion that their flight experience was the most effective part of their training, despite the wide departures from the planned modes of operation specified in the guidelines, and the less than adequate performance of some experiment equipment. In fact, they petitioned management for another training flight opportunity, but were denied on the basis that such was beyond the scope of the mission plan.

Evaluation of EO Training

Management

Overall direction of EO training for the Joint ASSESS Mission was provided by the MPG, which defined general guidelines, extent of training, and schedules to coordinate the various experiments and to correspond with each EO's background and experience. The MPG in turn requested each PI to plan and implement the detailed training of the EOs assigned to his experiment. Plans and evaluation criteria were to be submitted to the Mission Manager, who would monitor progress at intervals and adjust schedules as necessary. It also was planned that the training program would consist of visits by the EOs to the various investigators' laboratories and a final, integrated-payload training period after installation of experiment equipment.

The original plans for EO training were never fully implemented. Management was provided with only three training plans and so had limited direct influence over program content and timing. Early training was not organized and effective, and later efforts, although more directed, were informal and emphasized the individual experiment, rather than an integrated payload. Cross-training on secondary assignments was incomplete, while coordination within experiment groups and between primary and secondary experiments was almost entirely missing. The Meudon and New Mexico PIs prepared operational procedures for the EOs. The remaining PIs were too busy with their experiments to prepare procedures in final form, and the principal burden of this work was left to the EOs. In retrospect, it was helpful for the EOs to participate in the preparation of the procedures lists.

Laboratory Training

All four EOs made visits to the laboratories of their prime experiments, but secondary experiments were not so favored. A comparison of EO assignments (table 4) with the training calendar (fig. 34) shows that none of the EOs had received training on all his experiments prior to arrival at Ames. Of the four EOs, Operator B had by far the most experience both in Europe and the United States, and missed training only on the Colorado experiment, which was one of his secondary assignments. Operator A, with less than half as much training, covered all his experiments except New Mexico. Operator C started

late as an EO but managed good coverage of his U.S. assignment (except for Colorado), and training on his two European experiments was accomplished at Ames. Operator D had spent the least training time prior to his arrival at Ames - only one day on his primary experiment - and all his secondary training was deferred until the integration period at Ames.

Training in the home laboratory was supposed to include both a theoretical and practical base of knowledge. In all cases, theory instruction consisted of exposure to scientific and experiment-related literature, as well as comments by the PI. However, practical training was incomplete, largely as a result of delays in hardware development. Although subsystems and prototypes were available, in no case was it possible to operate the full experiment at a home laboratory in the same configuration that was installed in the aircraft. The Meudon and New Mexico experiments were operational during such visits, but not in their final configurations; the rest were in varying stages of development and checkout, seriously limiting opportunities for the EOs to obtain practical training. Because of this lack of opportunity, all four EOs stressed participation in experiment installation and checkout as the best way to understand possible problems and their troubleshooting. Firmer management control of the ERR function also would enhance training effectiveness by advancing the hardware completion date.

Hands-On Training

Because of deficiencies of the training program, the integration period at Ames loomed more importantly than had been planned. Even during this period, however, the EOs were not able to get all the time they hoped for in actual hands-on operation of the experiments. Several evening observation sessions were set aside, ostensibly for training, but they actually were used more by the PIs in final checkout. Three of the four EOs specifically mentioned this point as a deficiency in training. The fourth EO, Operator D, was actively engaged during most of this time in helping the Ames PI get his equipment ready.

The EOs concerned with multiple experiment groupings were not able to work with the groups of experiments until after their installation in the aircraft, and none of the EOs had an opportunity to operate their experiment groupings under time constraints until their one EO training flight. All felt this to be a deficiency in training, but one that could be overcome by use of a properly designed simulator.

Summary of Training Experience

Table 6 provides the total training experience of the four EOs. Time spent on primary and secondary assignments is identified as "classroom" training (i.e., lecture, study, observation) and "hands-on" training, and each of these is again subdivided into theory, operations, etc. Note that records of laboratory training were more complete than those taken during the integration period, and corollary information has been used where necessary to estimate training data. The emphasis on primary and secondary experiments varied widely in the laboratory but was centered on the former during final integration and flight training; classroom training was predominant in early training, and

TABLE 6.- OVERVIEW OF EO TRAINING EXPERIENCE

EO	Amount of training							
	PI laboratories				Integration site			
	Days	Hours	% Effort		Days	Hours	% Effort	
			Primary	Secondary			Primary	Secondary
Operator A	24	135	25	75	26	240	60	40
Operator B	66*	385	50	50	28	255	55	45
Operator C	21	130	70	30	27	250	70	30
Operator D	1	5	100	0	25	235	70	30

*Plus 40 days as de-facto co-investigator on primary experiment.

(a) Amount of training.

EO	Type of training - % of effort							
	PI laboratories				Integration site			
	Primary		Secondary		Primary*		Secondary	
	Class-room	Hands-on	Class-room	Hands-on	Class-room	Hands-on	Class-room	Hands-on
Operator A	65	35	70	30	35	65	45	55
Operator B	70	30	80	20	35	65	55	45
Operator C	55	[illegible]	75	25	55	45	70	30
Operator D	90	10	None	None	35	65	55	45

*All inflight training on primary experiments.

(b) Type of training.

EO	Location	Classroom training, %			Hands-on training, %	
		Theory	Opera-tions	Mainten-ance	Operations	Maintenance
Operator A	PI laboratories	40	45	15	85	15
Operator B		60	30	10	30	70
Operator C		50	35	15	60	40
Operator D		35	35	10	100	0

EO	Location	Integra-tion	Opera-tions	Mainten-ance	Integra-tion	Opera-tions	Mainten-ance
Operator A	Integration site	45	30	25	10	80	10
Operator B		10	60	30	25	60	15
Operator C		10	70	20	20	75	5
Operator D		15	65	20	25	50	25

(c) Subject material of training

NOTE: Laboratory training data from EO records; on-site data from various sources, thus less accurate.

..ODUCIBILITY OF THE
...GINAL PAGE IS POOR

hands-on training later; and operations training, generally, outweighed maintenance by a factor of ˙.

These variations are reasonable, expected trends that reflect the EOs' development from introductory theory to operation in flight. Individual differences can be seen to reflect the amount of training, its timing, and the previous experience of the EO.

Two of the EOs specifically used the word "casual" in summing up their assessment of the training process, and all stated that the training program could have been better organized, though they realized that the PIs were really too occupied with continuing development and checkout to give the training program the attention it needed.

Despite the substantial critical comment about the training process, the EOs agreed that their training was at least marginally adequate by the time the simulation mission started.

MISSION GROUND OPERATIC

This section addresses the on-ground operations of the active period of the Joint Mission, beginning with experiment integration at the experimenters' home location and at Ames, a phase of the simulation mission that is analogous to anticipated Spacelab integration operations. Experiment checkout and final EO training followed. Then came the week of the simulation itself, followed by two additional weeks of PI data flights. EO participation is indicated, as appropriate, often in the context of activities that furthered their training. Management functions specifically oriented to the simulation week are covered in this section. Significant mission events are summarized in table 7.

TABLE 7.- SUMMARY OF MISSION EVENTS

Date	Activity
Up to April 20, 1975	Experiment development and integration at experimenters' laboratories
April 20-30	Shipment to Ames
April 21-May 15	Payload integration and checkout
May 20-30	EO ground training
	Final experiment checkout
	Three PI checkout/data flights, one EO training flight
May 29	Mission readiness review
June 2-7	Five-flight simulation period - EOs operated equipment
June 8	Debriefing for simulation period
June 9-20	Seven PI data flights - PIs operated equipment
June 23-24	Removal of experiments
June 25-30	Shipment to experimenters' laboratories

Payload Integration

One of the key operational features of Spacelab is the concept and approach for experiment-related ground operations, covering the activities from the start of integration to final checkout in the Shuttle Orbiter. Four discrete levels of Spacelab experiment integration have been defined in reference 14:

> Level IV: Integration and checkout of experiment equipment with individual experiment mounting elements (e.g., racks and pallet segments*).
>
> Level III: Combination, integration, and checkout of all experiment mounting elements (e.g., racks, rack sets, and pallet segments*) with experiment equipment already installed, and of experiment and Spacelab software.
>
> Level II: Integration and checkout of the combined experiment equipment and experiment mounting elements (e.g., racks, rack sets, and pallet segments*) with the flight subsystem support elements (i.e., basic module, igloo, and extension modules when applicable*).
>
> Level I: Integration and checkout of the Spacelab and its payload with the Shuttle Orbiter, including the necessary preinstallation testing with simulated interfaces.

These integration activities are as independent of each other as possible: they involve different hardware items (flight hardware and GFE) and will take place at different times and different locations (ref. 14). To some extent, the integration of airborne experiments has analogous features, although not as distinctly separable as those listed. The Joint Mission payload integration schedule and activities are briefly described below. Spacelab equivalents are noted where appropriate. The final presimulation milestone was the mission readiness review (MRR), in which payload status and EO readiness were evaluated.

Integration Schedule

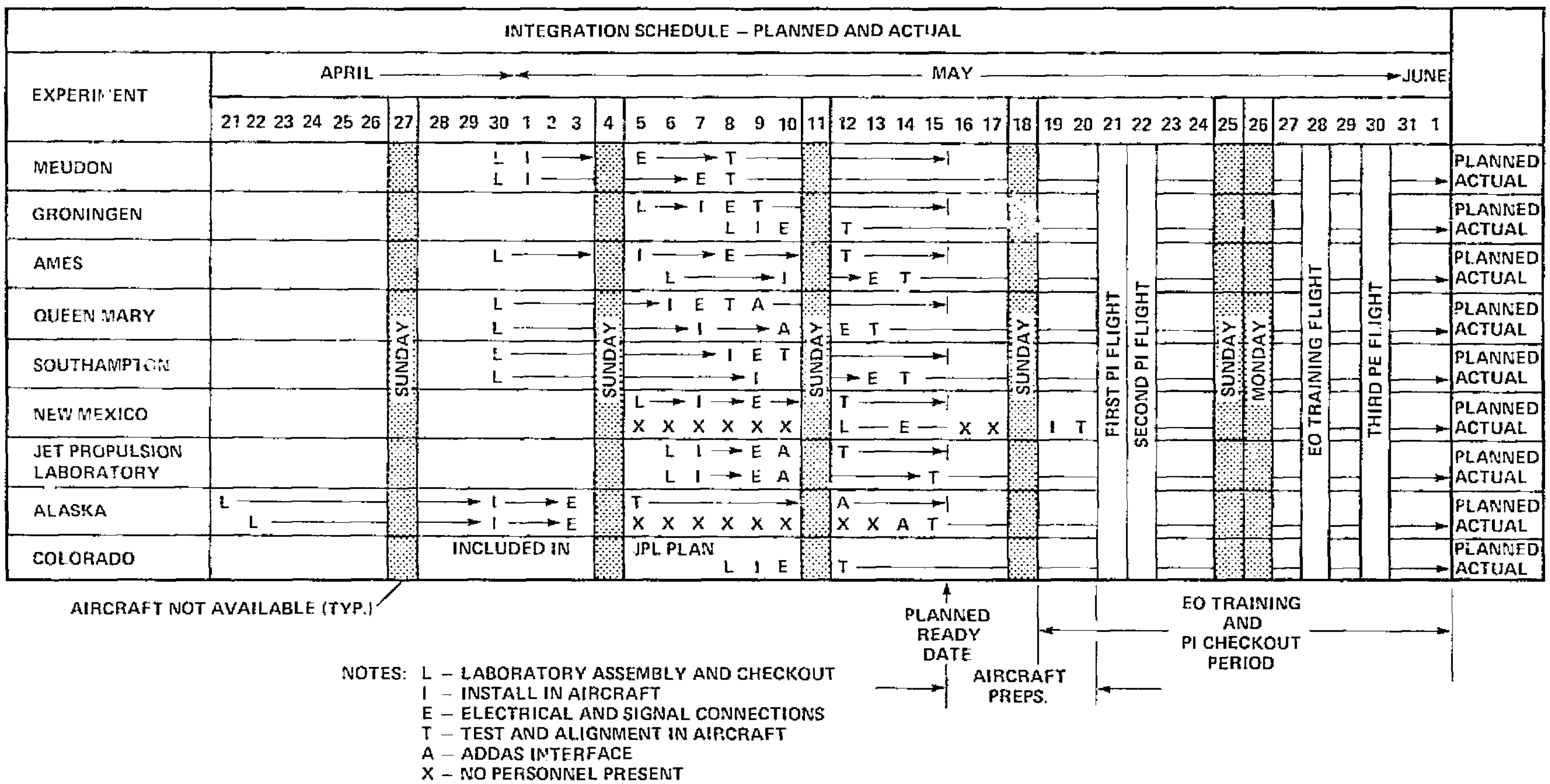
A schedule was prepared to coordinate the flow of on-site integration activities so that all experiments would be in a flight-ready status aboard the aircraft by May 15. This was a mandatory deadline to allow adequate time for inflight verification of payload mechanical integrity, pilot proficiency flights, and the subsequent PI and EO checkout flights. The schedule covered the following activity classes: laboratory assembly and checkout (L), installation on the aircraft (I), electrical hookup in the aircraft to power and signal leads (E), test and alignment in the aircraft (T), and ADDAS interfacing (A).

Table 8 shows the scheduled and actual sequence of payload integration activities. A comparison of planned and actual events shows that most experiments started out on schedule with work in the ASO laboratory. Mechanical

---

*Spacelab flight hardware.

TABLE 8.- INTEGRATION SCHEDULE - ACTUAL AND PLANNED



REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR

installation in the aircraft started on schedule for the majority of experiments and was generally completed in the allotted time; in the later stages, there were usually several activities going on concurrently. The New Mexico experiment was delayed a week by absence of personnel (prearranged and approved by the Mission Manager), and not all installation activities were completed until after the planned cutoff date.

With the one exception noted, the May 15 deadline was met with respect to interfaces with aircraft and experiment support systems; airworthiness and safety requirements were satisfied. For all experiments, however, much of the next two weeks was spent in further checkout as the principal activity instead of EO training. For this reason, test and alignment is shown as the principal activity in that period.

Equivalent Level IV Integration

At this integration level, a good analogy exists between aircraft and Spacelab. Varying amounts of Level IV type integration were carried out by all Joint Mission PIs in their home laboratories. Most PIs whose experiment occupied rack volume obtained standard racks from ASO for home laboratory integration of electronic components. These racks accept standard 48-cm (19 in.) electronic panels and are mounted as a unit on the aircraft seat rails. Thus, the PI can ensure optimum arrangement and proper cabling of electronic components in the rack before shipping his experiment to Ames. The Meudon/Groningen experimenters built a si e mock-up to assist in their home lab integration. They found this procedure desirable to determine the interrelationships of the five racks of equipment and the telescope, and to allow precise precutting of the many connecting cables.

Some mechanical integration of instruments with special support structures also took place at home laboratories, but the majority of this work was done at Ames, where most integration involving interfaces with aircraft structure was planned. Ames design engineers made a vital contribution to this effort, both by consulting with PIs and by designing the many mounting structures that were fabricated in Ames shops. The most active shop, Metals Fabrication Branch, provided nearly 2700 man-hours of effort to the Joint Mission, including the final integration of standard racks and special supports in the aircraft.

Home laboratory integration was insufficient in four cases. The Alaska experiment encountered problems in optical alignment at Ames, some of which were never adequately resolved. The Ames dewar did not fit to the Meudon telescope. A primary instrument for JPL was not delivered from the manufacturer until the beginning of the flight period. And the TV camera support for Southampton had to be reinforced to meet aircraft load requirements.

Incoming Inspection, Assembly, and Level IV Approval

Each experimenter was responsible for examining his equipment at Ames for damage in shipping. The only serious shipping damage involved the Southampton TV camera tube. The focusing coils were not suitably secured for shipping shocks and had slipped an inch or more resulting in breakage of fine wires.

After preliminary inspection, components and eventually the completely assembled experiments were given operational checks. Components that were not shipped in the standard racks, and those requiring special supports built at Ames, were mounted in the flight configuration. Single-phase induction motors used to drive vacuum pumps were modified for spark elimination; the current-carrying function of the starting switch was replaced by a solid-state circuit.

Prior to transfer to the aircraft, each assembly underwent a final inspection for compliance with mechanical specifications, which included the use of aircraft-acceptable hardware, the use of restraints to prevent damage in the event of untoward accelerations, and the proper placement of equipment so that the overturning and rail-fitting loads and moments were below the allowable maximum.

During the lab inspection/check period, the University of Alaska team made the first assembly of their complete optical system in conjunction with Ames personnel. This system comprised a stabilized mirror, 35-cm telescope, and 1-m Ebert-Fastie spectrometer. In addition, provision had to be made for reflecting the beam into the University of Colorado 12.5-cm Ebert spectrometer when desired. This optical system was not in reasonable operating condition until the second checkout flight.

In effect, the activities outlined above amounted to a review and approval of Level IV integration by those responsible for safety. For Spacelab, such functions may well be done before the experiment is shipped from the home laboratory.

Integration and Checkout (Level III, II, and I Equivalents)

Following the inspection and Level IV approval, equipment was loaded aboard the CV-990 for the remainder of the integration process. Because the aircraft is a simpler system than the Spacelab/Orbiter, the remaining levels of integration were not as distinct as those planned for Spacelab and may be considered as a single level combining the features of Spacelab Levels III, II, and I.

The integration processes aboard the aircraft include the following, not all of which were necessary for every experiment:

Placement and tiedown of equipment racks.

Placement of special mounting fixtures.

Installation of special optical windows.

Installation of other special facilities such as pumps, cryogen supply, purge gas supply, etc.

Connection of racks to electrical power.

Connections to and from data system.

Connections to aircraft instrumentation.

Measurement of electrical loads.

Checkout of equipment.

Final inspection - mechanical, electrical, safety (add padding if needed to prevent personal injury).

Installation of black shrouding curtains.

The mechanical and electrical integration took a total of two weeks. The Airworthiness and Flight Safety Review Board then met to determine that the aircraft and its payload were physically ready to fly. No major problems were found during this review.

Figure 35 shows a floor plan of the aircraft cabin with the location of the various experiments. Figure 36 is a photograph of the integrated payload, taken from the front of the cabin. For this mission, the general location of the experiments was dictated by the requirements of EO operation. The three atmospheric physics experiments - Queen Mary College, University of Southampton, and University of New Mexico - were adjacent in the front of the cabin. The location of the Meudon telescope was dictated by the use of the overwing escape hatch for the telescope mounting. Primary telescope controls and controls for both the Groningen and Ames photometers were mounted in two standard racks directly opposite the telescope. The remaining astronomical equipment, the JPL/Alaska/Colorado experiment, was installed aft of the Meudon telescope. The ADDAS equipment was installed in its normal location in the aircraft.

Special light shields were used for Southampton, New Mexico, and JPL/Alaska/Colorado equipment to keep extraneous light from otherwise open optical paths or to protect particularly sensitive detectors.

A desk and a special work area simulating the bench space planned for Spacelab was installed on the right side of the aircraft just aft of the ADDAS area (figs. 37 and 38, respectively). A standard supply of basic tools and test equipment, developed in part by MSFC from Skylab experience, was provided. Experimenters augmented the standard supply with experiment-specific tools as necessary. Specific information on tools and test equipment will be found in appendix B to this report.

When payload integration was complete, each experiment and the entire installation was carefully checked out on the ground. As experiments were turned on, others were checked for possible electrical interference. Signals to the ADDAS were double checked before the actual connection was made to avoid electrical damage to the computing system. The aircraft was positioned in as dark an area as possible to permit astronomical observations, and the instrumentation was operated to the extent permitted at ground level. In this way, it was possible to determine whether experiments making astronomical observations were operating properly, although signal strengths in both the UV and the IR were far below those expected at altitude. For skyglow experiments, it was possible to check sensitivities, although not in the exact wavebands desired at altitude. Full checks were made of cryogenic cooling. A total of 20 hr was devoted to this activity.

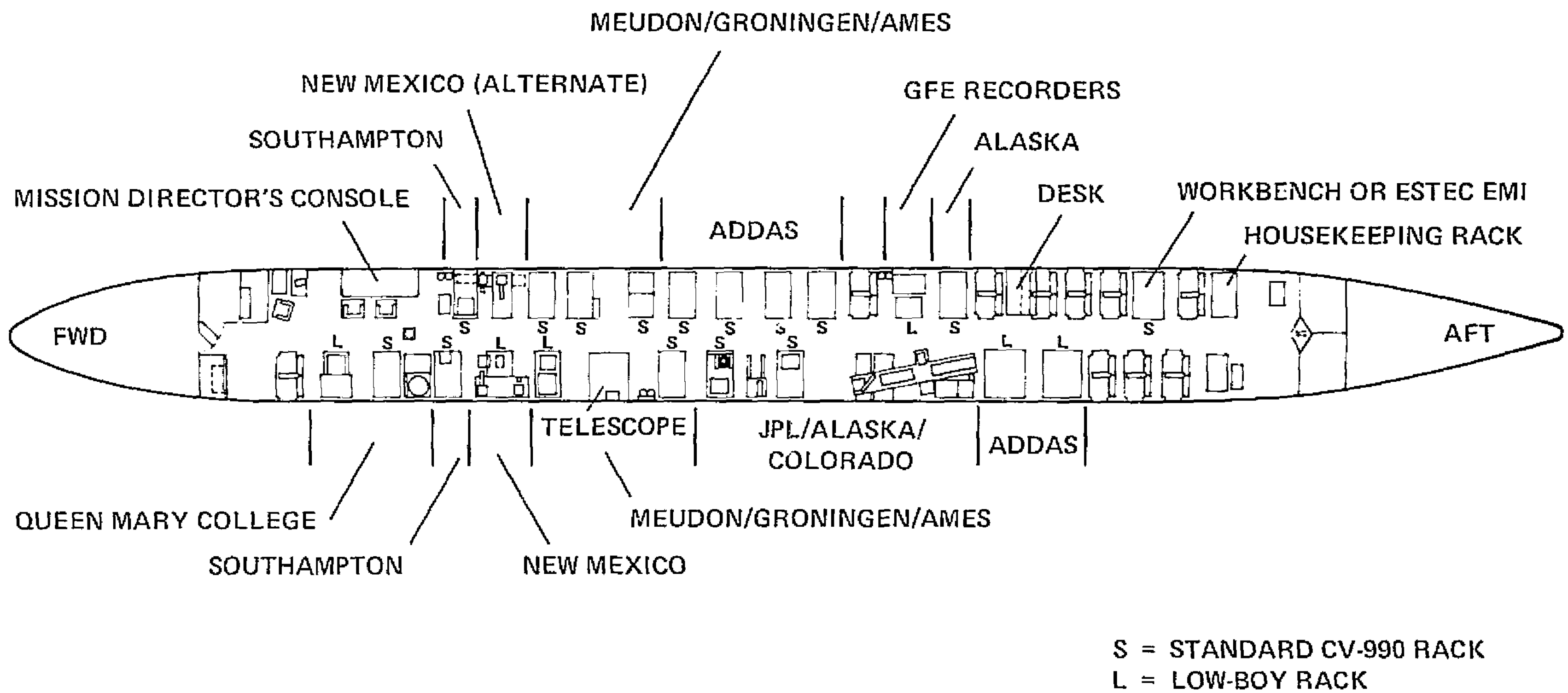


Figure 35.- Arrangement of experiments in aircraft cabin.

Figure 36.- Integrated experiment payload in CV-990 aircraft.

REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR

Figure 37.- Operators' desk and communications center.

PRODUCIBILITY OF THE
GINAL PAGE IS POOR

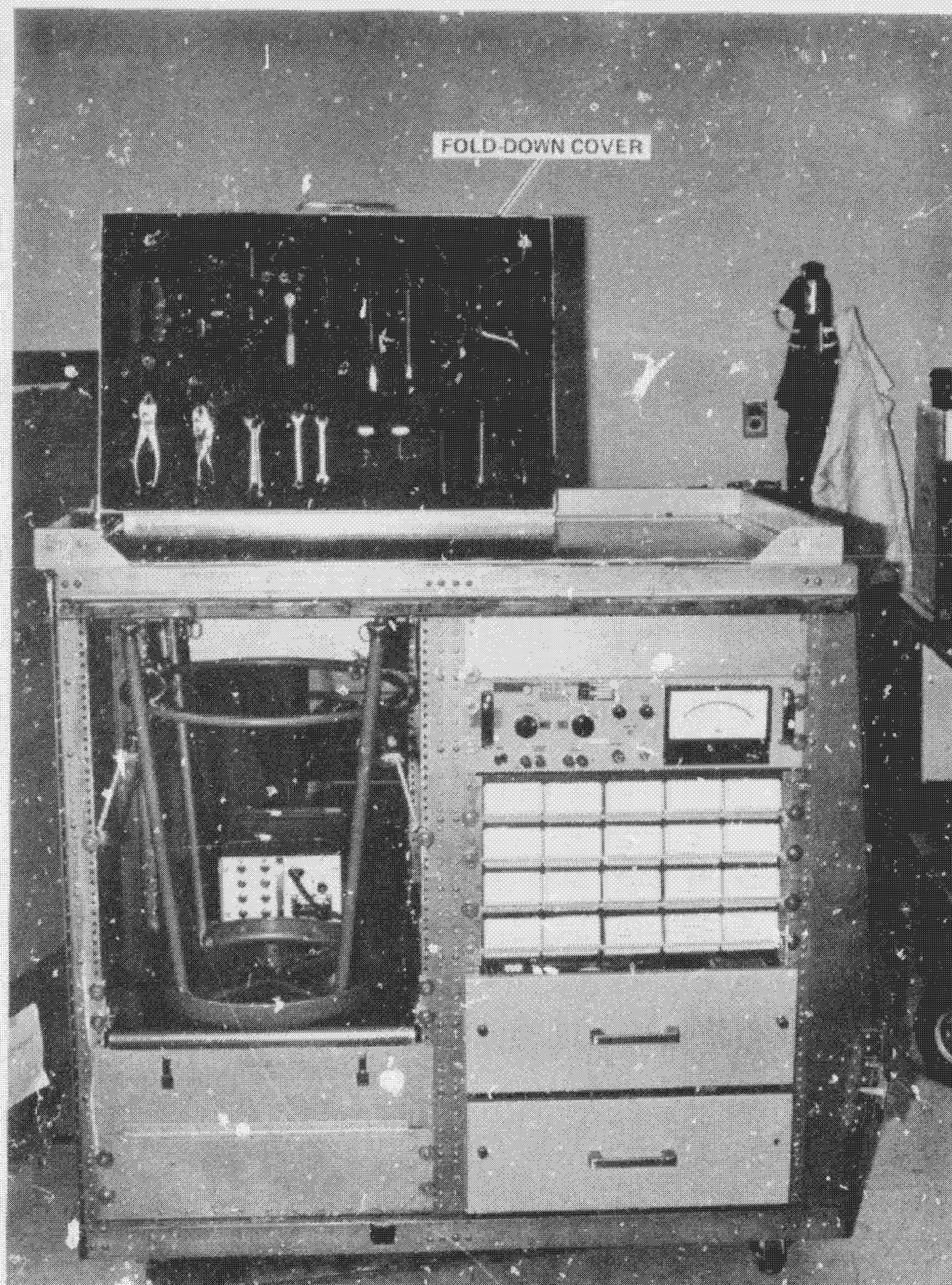


Figure 38.- Operators' work area.

PRODUCIBILITY OF THE
INAL PAGE IS POOR

Mission Readiness Review

The status of both experiments and EO training was assessed during an informal MRR on May 29, following the last scheduled flight of the presimulation period. The review was chaired by the Mission Manager, and attended by the PIs, EOs, ASO participants, and MPG representatives. It was soon apparent that payload preparations for the simulation mission had not been completed. Only one or two experiments were in a ready status. In each case, however, the outstanding problems had been identified and were on the way to solution. Several changes in the handling of ground support equipment were requested to facilitate EO activities during the confined period. Because of the emphasis on hardware problems EO training had not progressed to ready status.

It was agreed that final preparations could be completed in time for the scheduled start of the simulation period. To this end, requests were made for a fourth premission flight for experiment checkout, and for ground support personnel as necessary to operate experiments for EO training through the weekend. Both requests, which subsequently were implemented, were changes to the mission plan, justified by the immediate circumstances. A second operator training flight was also requested. It was not approved, however, as the MPG representatives judged it to be a serious breach of mission guidelines. In a sense, the MRR experience was a capsule summary of mission preparations for the previous year, and brought to focus a number of important points:

1. Experiment development delayed beyond the ERR date will adversely impact EO training and final integration activities.

2. Mission planning should allow a contingency period for unexpected problems during integration and simulator testing.

3. Individual experiments that make up a composite payload, if allowed to develop separately, may not achieve the desired result when integrated, and some compromise of research objectives may result.

4. When experiment operators are to perform time-shared, multiple experiment functions, the prerogatives of the Mission Manager should be adequate to assure compliance with milestone schedules for experiment development and operator training.

5. Experiment development must be monitored effectively so that delays can be recognized promptly and early responses facilitated where scheduling is flexible, and to minimize impacts on other experiments and support functions.

6. Early transition from passive to active hands-on training is important. Only by this means can an operator develop the skills that allow concentration on results rather than procedures.

Aircraft Ground Operations

Between flights, the CV-990 was parked outside the main NASA hangar (except during fueling operations), and air-conditioning equipment was attached in a manner similar to standard airline practice. Electric power was provided to the aircraft by an MG set giving 400-Hz power. Figure 39 indicates the location of the aircraft on the ground and the disposition of support facilities required for the Spacelab simulation portion of the mission.

On a Spacelab mission, sleeping quarters will be provided in the Orbiter portion of the Space Shuttle. During the one-week simulation period of the Joint Mission, Orbiter living quarters were simulated by a lift-van truck (fig. 40), which provided sleeping accommodations, and space for sanitary facilities and for preparation and eating of light meals. When the aircraft was not flying, the truck bed was lifted to mate with the rear passenger door of the aircraft and became an integral part of the aircraft interior, similar to Spacelab/Orbiter living quarters.

The Mission Operations Center (MOC) was located in trailers adjacent to the hangar (fig. 39). The operations trailer had a separate room for the Mission Scientist, the Operations Manager, and MPG representatives from NASA and ESA (fig. 41). The larger room had a conference/communications area, an area for official observers from NASA and ESA and one for visitors. A connected but separate space was provided for the PIs to work on flight planning and data evaluation. In general, the PIs spent about 16 hr a day in the MOC, from 0300 to 1900, and slept while the aircraft was flying. The MOC was not used during the nonsimulation portions of the mission.

While on the ground, the aircraft was connected to the MOC by two channels of two-way voice link and one channel of TV downlink - a system equivalent to that planned for Spacelab (fig. 41). Two TV cameras were available aboard the aircraft, one fixed with the operators desk in its field of view and the other a portable set that could be focused on anything of interest.

MISSION FLIGHT OPERATIONS

This section covers the flight-related activities of the Joint Mission, beginning with the first payload checkout flight on May 21. Flight management, operations schedules, and PI activities are described. But the major emphasis is on the work of the EOs - their assigned tasks, operating procedures, interactions for mutual support, and a brief comment on their overall performance.

Table 9 summarizes all mission flights involving the EOs and PIs. (Flights solely for checks on the aircraft and for pilot proficiency are not included in the listing.) The purpose of each flight is shown. Two flights involved two segments: once by plan and once for aircraft servicing. Flight times are shown to indicate that almost all flights took off in early twilight to permit observation of Venus. Flights 15 and 16 involved daytime observation segments.

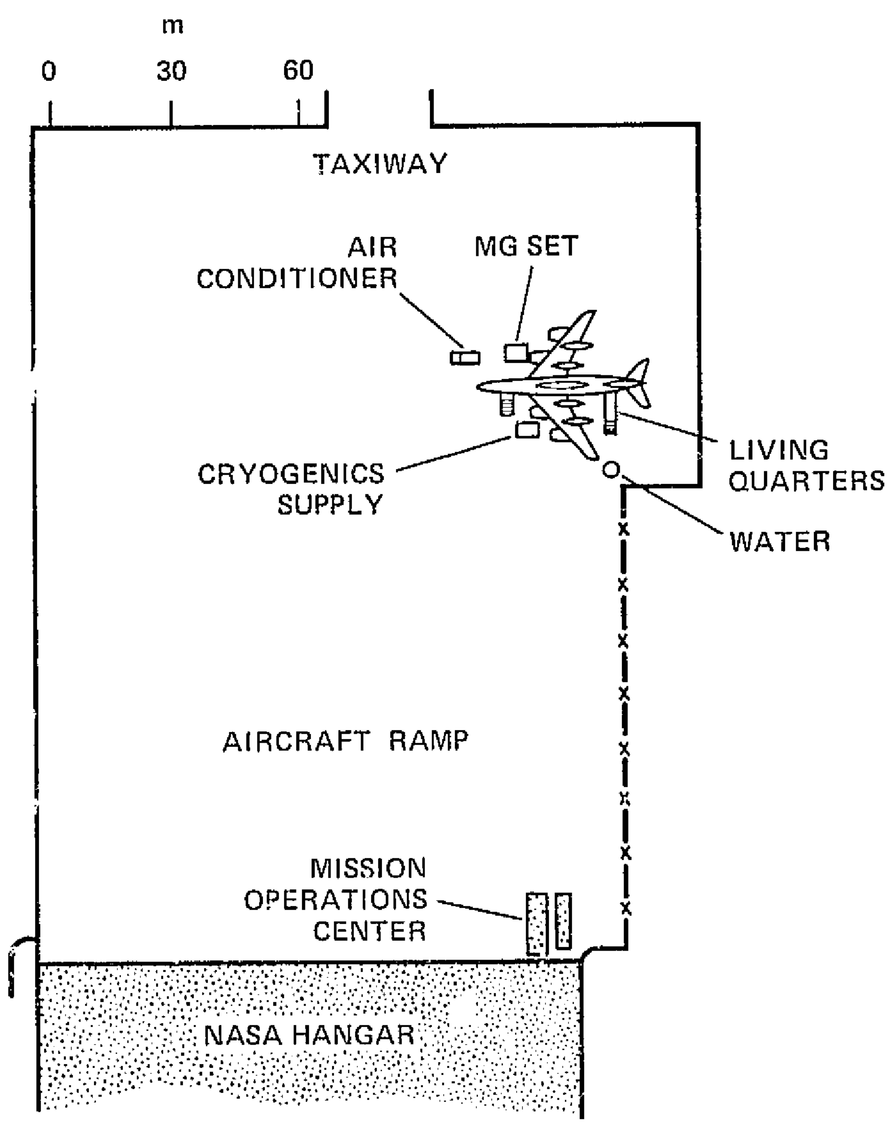


Figure 39.- Location of aircraft and support facilities during simulation period.

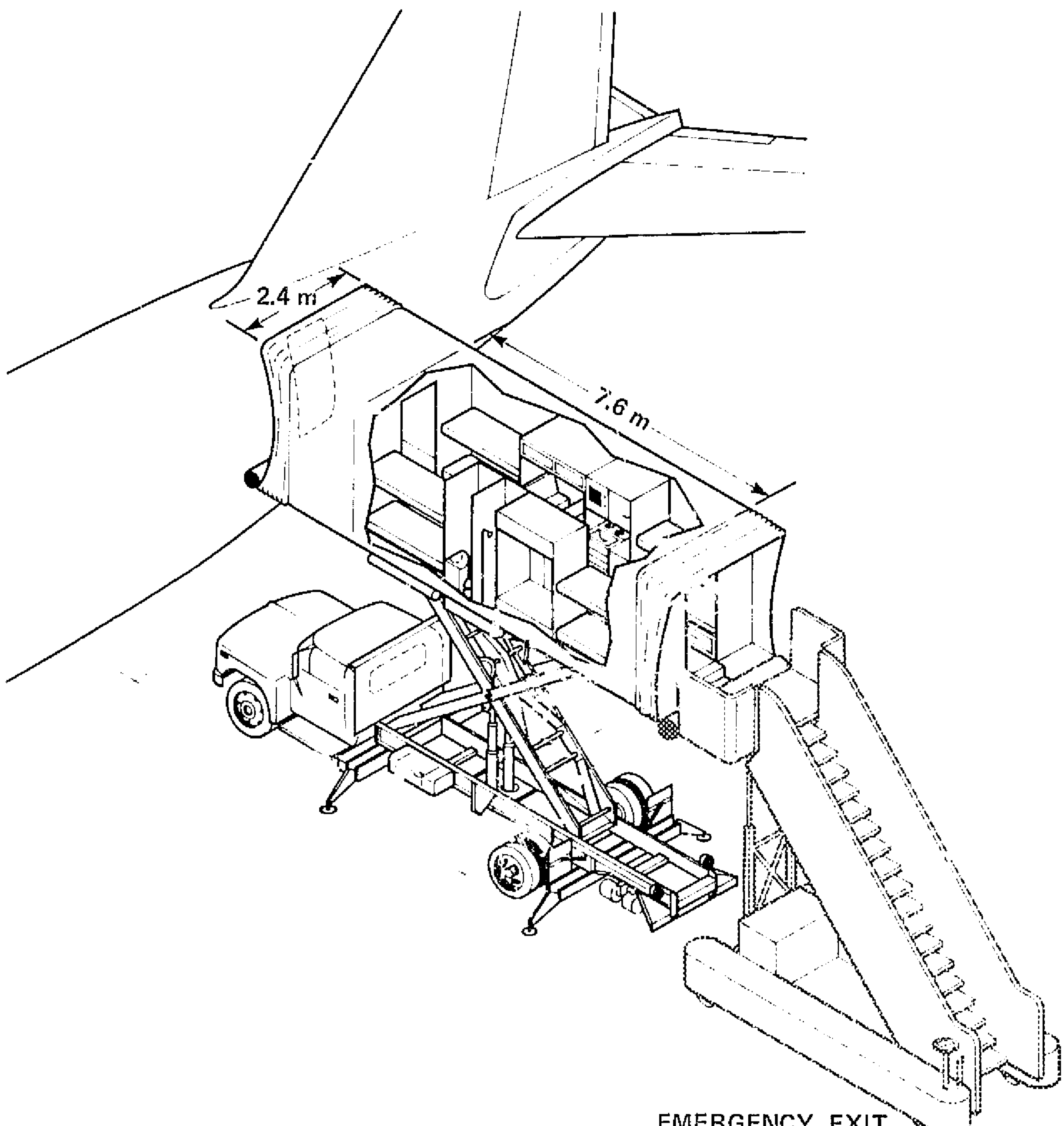


Figure 40.- Lift-van living quarters.

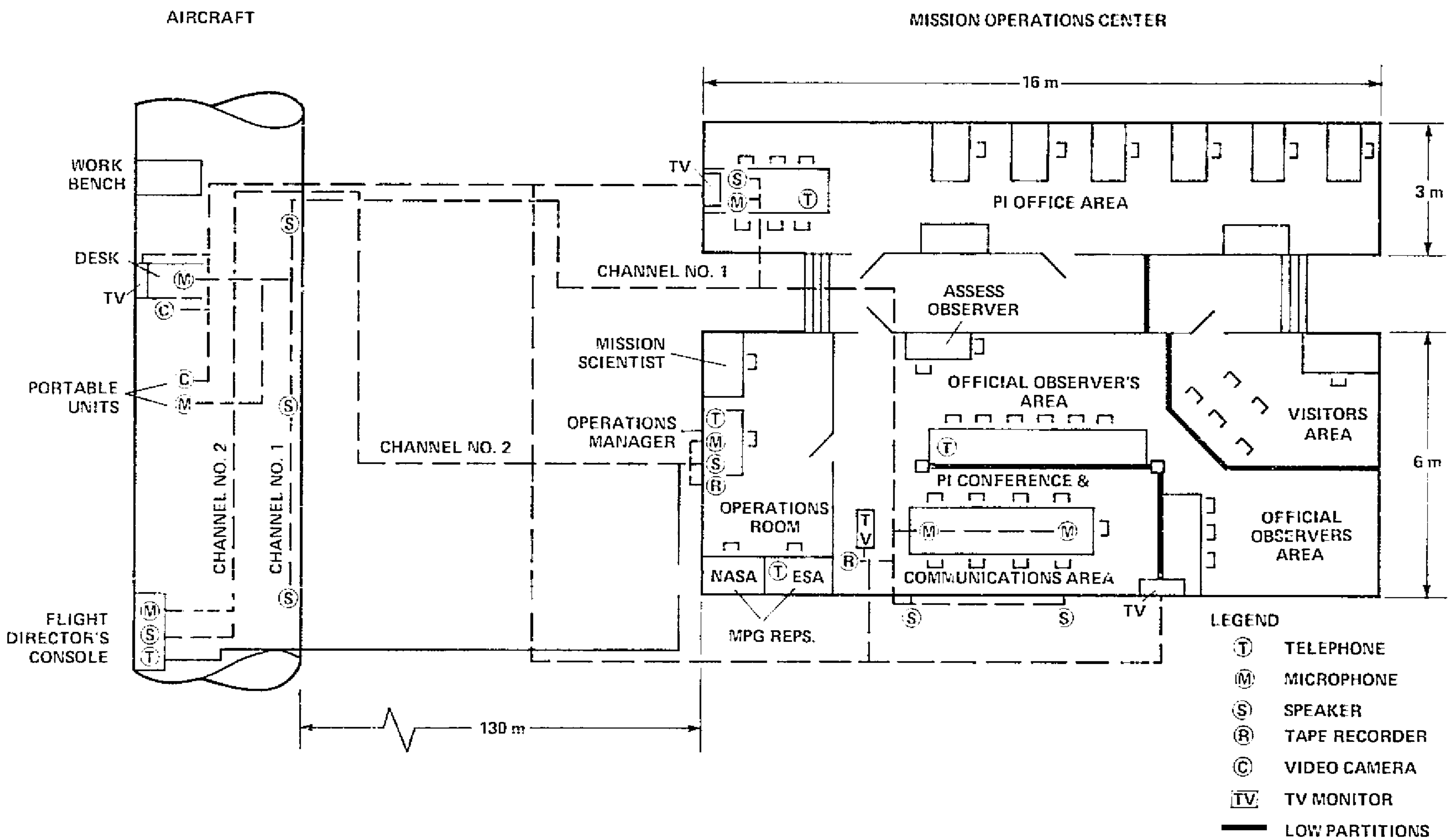


Figure 41.- Mission operations center and communications layout; ground operations.

REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR

TABLE 9.- JOINT ASSESS MISSION - LIST OF FLIGHTS

Flight number	Local date and time				Type of flight
	Date	Takeoff	Land	Duration	
1	5/21	2101	0306	6h 05m	PI checkout & data
2	5/23	1920	2331	4h 11m	PI checkout & data; EO training on US1
3	5/28	1940	0241	7h 01m	EO training
4	5/30	1932	2259	3h 27m	PI checkout & data
5	6/2	1939	0040[1]	4h 01m	Spacelab simulation
		0458[1]	0548	0h 58m	Transit to Ames
6	6/3	1957	0200	6h 03m	Spacelab simulation
7	6/5	1938	0150	6h 12m	Spacelab simulation
8	6/6	1930	0112	5h 42m	Spacelab simulation
9	6/7	1932	2302	3h 30m	Spacelab simulation
10	6/11	1935	0200	6h 25m	PI data
11	6/12	1955	0201	6h 06m	PI data
12	6/13	1950	0202	6h 12m	PI data
13	6/16	2012	0230	6h 18m	PI data
14	6/17	2112	0332	6h 20m	PI data
15	6/19	1400	1633[2]	2h 33m	PI data
		1907[2]	2300	3h 53m	PI data
16	6/20	1715	2316	6h 01m	PI data

[1]Nellis AFB, Las Vegas, Nevada.

[2]Davis-Monthan AFB, Tuscon, Arizona.

Management

Flight operations of the CV-990 involved coordinated activity by the following groups:

Flight operations (pilots and flight engineers)

Aircraft ground crew

Aircraft inspection

Navigators (ASO flight planners)

Experimenters (PIs and EOs)

Mission Scientist and Operations Manager (during the simulation week)

With the exception of aircraft inspection, these activities were coordinated by the Mission Manager. In consultation with the experimenters, he developed the flight plan requirements, which then were translated into a detailed plan for each flight by the navigators. During the simulation period, the Mission Manager could not be available on a 24-hr basis. He therefore delegated planning coordination with the PIs to the Mission Scientist, and ther support activities to the Operations Manager during that time. During the simulation period, the Operations Manager was also responsible for special facilities such as the MOC, the sleeping van, and the special communications equipment, as well as conduct of the briefing sessions before and after flight.

In flight, the Mission Manager controlled distribution of electrical power to experiments and controlled intercom channels (two). Acting as Mission Specialist, he was the contact between experimenters and flight crew, although the flight crew could switch into the experimenters' intercom circuit if necessary. The Mission Manager, with pilot approval, also could communicate with local ground stations via regular aircraft radio systems, but there was no occasion to do so during the mission.

Inertial navigation system (INS) and time-code readouts at the Mission Manager's station allowed the precise announcement of start and stop of the data legs of the flight, which the Mission Manager usually noted, along with other pertinent flight-path data, for his own reference. During the nonsimulation flights the Mission Manager's planning assistant became his in-flight assistant as well. He aided in manning the Mission Manager's station, thus freeing the manager for more frequent "at station" contact with the flight crew and experimenters.

Several specialists flew aboard the CV-990 to assist the experimenters and Mission Manager as required. An electronics technician checked optical windows after takeoff, maintained housekeeping electronics, and occasionally aided an experimenter (on nonsimulation flights). A stabilized-mirror specialist maintained these systems (one on flight 1 to 9, and two on the remaining flights), and participated directly in their operation as requested by experimenters. A computer-software technician kept the ADDAS system in operation, and took Polaroid pictures of the QMC Fourier transformed interferograms for

the EOs during the simulation week (these were transmitted down to the PI for evaluation). This specialist did not assist in problems with experimenter-provided minicomputers.

Presimulation Flights

Two checkout/data flights were planned. Three were flown (May 21, 23, and 30), the last being a short flight intended primarily to check the solution to Meudon telescope stability problems, but also to operate the JPL UV TAOF for the first time.

The Queen Mary, Meudon, JPL, and Alaska experiments encountered serious operational problems during the checkflights. QMC and JPL had EMI problems. The JPL difficulty was fairly obvious and was easily diagnosed, but the QMC problem was not even diagnosed as EMI until the fourth simulation flight (by an EO). Neither experimenter was wholly successful in eliminating the interference. JPL also found that their proposed hand guiding of an 8-in. telescope on an astronomical object was an impossible task. This task was deleted from EO activities, and a stabilized mirror was introduced into the system after the simulation period.

The Meudon telescope suffered from aerodynamic buffeting within the open cavity, which made consistent tracking very difficult. Before the last checkout flight, a thin mylar window was placed over the telescope port, which solved the buffeting problem but reduced the signal level and introduced icing problems that were not resolved during the simulation period. The Alaska problem was internal to the experiment: A faulty tape recorder repeatedly knocked out the experiment's computer. The problem was diagnosed after the EO training flight, and the tape recorder was removed from the experiment and repaired during the simulation week. It was reinstalled for PI flights.

One other less serious problem was encountered. New Mexico's image intensified pictures were distorted by unknown magnetic fields. This EMI was reduced considerably after the first flight, but was never completely eliminated.

Simulation Period

The schedule and specific flight plans for the simulation period were modified considerably because of aircraft engine trouble, although all five flights took place. The trouble developed about half way through the first flight, and data legs for two (or four) astronomical objects were aborted. The same problem occurred again on the second flight, but later in the flight. The aircraft was able to stay on planned course, but at a lower altitude (for greater engine efficiency of the three operating engines). Data on one astronomical object were severely degraded due to atmospheric absorption at the lower observational altitude. The troublesome engine had to be changed, delaying the mission one day. The last three flights were then flown as scheduled.

Schedule of Daily Activities

A master schedule of daily events (table 10) was developed to coordinate mission operations during the simulation week. Time blocks for major events were keyed to aircraft takeoff (T) and landing (L), to accommodate changes in flight plan required by priority experiments and/or target selection. This general schedule was supplemented daily by an hourly-events schedule as soon as the flight time was established, to enable PIs to arrange their experiment support activities.

The "Spacelab" workday began 7-1/2 hr before takeoff when the crew was awakened for breakfast. An unstructured period of 2 to 3 hr followed, for personal hygiene, experiment servicing, and EO/PI consultation. At T - 5-1/2 hr there was a 30-min preflight meeting of all participants to review mission status to date, to discuss the final flight plan for the day, and to respond to specific requests in support of the mission. From then until T - 1 hr, the primary activity was experiment preparation, with EO/PI consultation as required. In the late afternoon the EOs had their main meal of the day. Experiments were shut down (at T - 1 hr) and the final countdown before takeoff began.

The workday ended about 2 hr after landing. In the first hour, the aircraft was refueled and towed to the ground site, where communications and living quarters were attached. Data downlink activities and cryogenic servicing were completed before the flight debriefing at L + 1-1/2 hr. This 30-min session was used to communicate informat. n necessary for PI planning for the next flight, while the EOs slept. After a light meal (if desired), the EOs retired for the night. Figure 42 summarizes EO activity for a typical day.

Flight Activities

The EOs were allowed to go to their experiment stations a few minutes after takeoff, following the safety check of optical windows by the electronics technician. At station, the EO immediately began an experiment turn-on routine. This was a very busy time, with the turn-on generally continuing at various levels until the beginning of the first data leg, usually about 30 min after takeoff. The actual initiation of data operations varied with experiment type and atmospheric conditions required.

During the data collection period EO responsibilities varied with the experiments. Some required only periodic checks of proper operation, and others required stopping and resetting of start conditions. The cycle of checking, setting controls, and occasionally resolving an operational problem occupied essentially all of the EOs' time. Turn-off began about 20 min before landing, generally with the beginning of the descent from altitude. The assembly of data for downlink transfer to PIs did not begin until after landing. EO assignments during the five flights are shown in table 11.

TABLE 10.- SIMULATION WEEK DAILY SCHEDULE

Time (hrs)	Events	Location	Participants
L	Refuel aircraft	A/C	MM
L + 1	Lift van attached	A/C	MM
	Communication hookup	A/C	MM, OM
	Cryogenics servicing	A/C	EO
	Data down link	A/C, MOC	EO, MM, PI, OM
	Hand carry		
	• ADDAS tapes to IBM 360 — Log in through Operations Manager		
	• ADDAS hard copy to PI — Log in through Operations Manager		
	• ADDAS printout to PI — Log in through Operations Manager		
	• Film to Photolab — Log in through Operations Manager		
	Dump Southampton video record	A/C, MOC	EO, PI
L + 1-1/2	Flight debriefing	A/C, MOC	OM, EO, PI, MM, MS
L + 2	Silence A/C	A/C	EO, MM
	EO meal (optional)	A/C	EO, MM
	Sleep	A/C	EO, MM
	PI-MS consultation	MOC	PI, MS
	Preflight planning		
T - 7-1/2	PI-MS consultation	MOC	PI, MS
	Preflight meeting preparations		
	EO wakeup, shower, breakfast	A/C	EO, MM
T - 6-1/2	EO-PI consultation	A/C, MOC	EO, PI
	Free time		
T - 5-1/2 Approximate time 2PM	Preflight meeting	A/C, MOC	EO, PI, MM, MS, OM
	Formalize final experiment operations		
	Final flight plan		
	Passenger manifest		
T - 4-1/2	Start experiment preparations		
	Film and tape loading	A/C	EO
	Cryogenic loading	A/C	EO
	EO-PI consultation	A/C, MOC	EO, PI
	Meal/free time		
T - 1	Loose item stowage	A/C	EO, MM
	Passenger boarding	A/C	EO, MM
	Lift van removed	A/C	OM
	Stop N_2 purge of cavity	A/C	EO, MM
	Communication disconnect	A/C	EO, MM, OM
T - 1/2	Door closure	A/C	EO, MM
T - 0	Takeoff	A/C	EO, MM
	Box lunch available in flight		

NOTE: L + 1-1/2 and T - 5-1/2 meetings were mandatory for all indicated participants - at least one PI per experiment. Operations Manager on duty 24 hr/day.

L:	landing	MOC:	Mission Operations Center	MM:	Mission Manager
T:	takeoff	PI:	Principal Investigator	MS:	Mission Scientist
A/C:	aircraft	EO:	Experiment Operator	OM:	Operations Manager

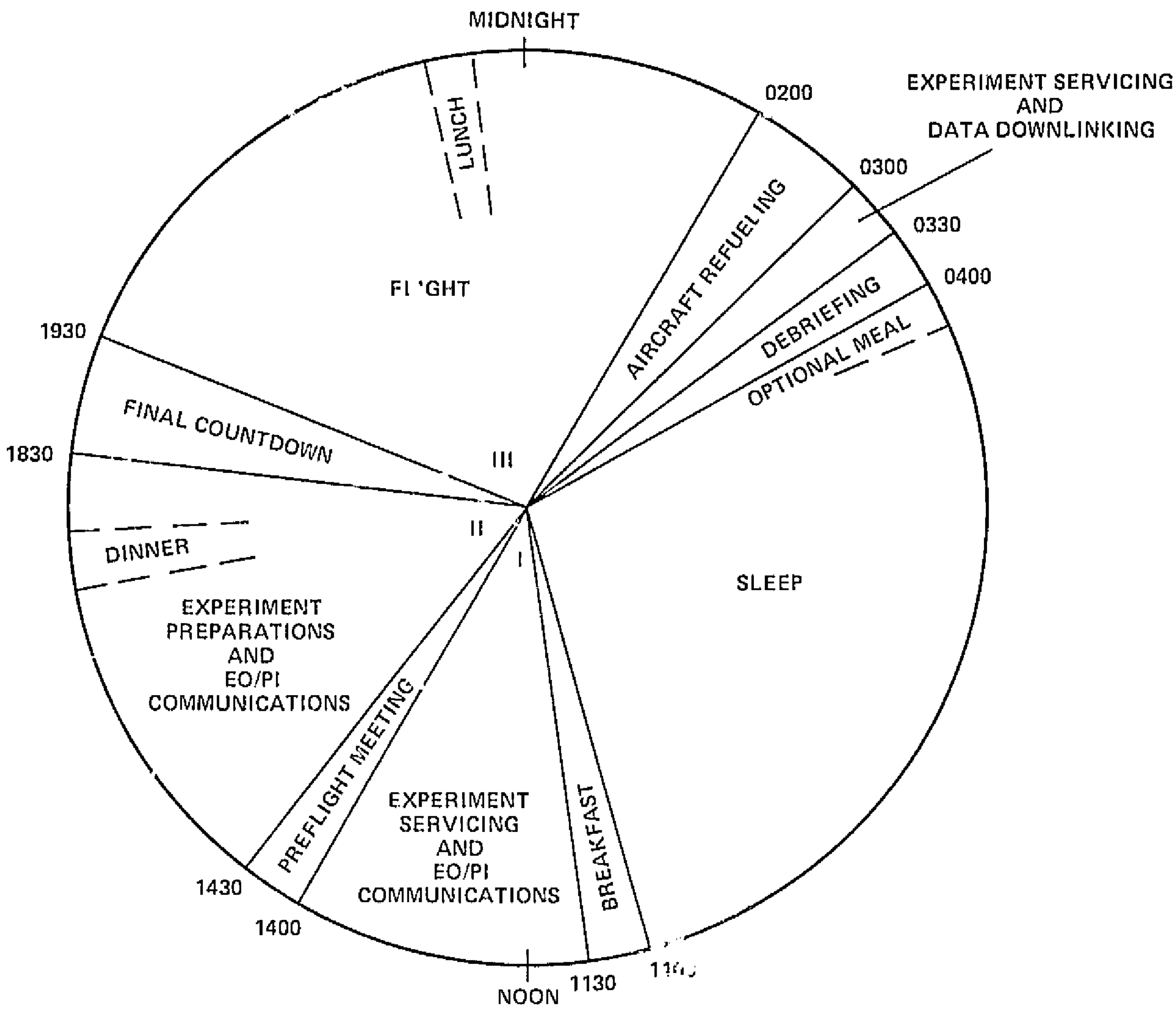


Figure 42.- EO activities for a typical day during the simulation period.

TABLE 11.- EO ROTATION SCHEDULE - SIMULATION PERIOD

Experiment	Flight number				
	5	6	7	8	9
Southampton Queen Mary College New Mexico	Operator B*	Operator B*	Operator C	Operator A	Operator B*
Meudon/Groningen Ames	Operator A* ---	Operator A* ---	Operator A* ---	--- Operator D*	--- Operator D*
JPL/Alaska/Colorado	Operator C*	Operator D	Operator B	Operator C*	Operator C*
Not assigned	Operator D	Operator C	Operator D	Operator B	Operator A

*Prime assignment.

Inflight Experiment Operations

Despite the disparity in number of experiments operated by the EOs, the actual workloads were fairly equal. The single EO operating the Queen Mary College, the University of Southampton, and the University of New Mexico experiments was always very busy when starting them up. His work was complicated somewhat by the fact that there was no coordinated control panel for the three experiments, and he had to move about the cabin to the location of each experiment (fig. 43). The EO operating the Meudon telescope, whether with the Groningen detector or the Ames detector, did not have to move around as much, but was very busy with the telescope controls and, in the Groningen case, with the telescope computer terminal as well. His location was physically uncomfortable: No seat was available, and the controls were placed low in a rack, requiring that he sit on the floor to operate them. The EO operating the JPL/Alaska/Colorado group also had several locations of activity, three control racks and the two telescopes.

Some specific comments about the operation of each experiment follow. The detailed procedural information prepared for the EOs, by the EOs and PIs, will appear in appendix A to this report.

Meudon/Groningen. Figure 44 is a flow diagram of operations required for this experiment. A 15-page booklet of operating procedures details the sequence of operations under each block shown. For the most part, operations, once initiated, were automatic.

To guide on an object, the EO used a small joystick telescope position control and a TV display of the tracker scope field of view. The guide object was brought to a small rectangular area of the screen, indicated by two short parallel bars, within which one could switch to automatic track. To allow for offset tracking, the area was not necessarily at screen center. After switching to automatic track, the EO initiated the computer program that controlled the recording of data.

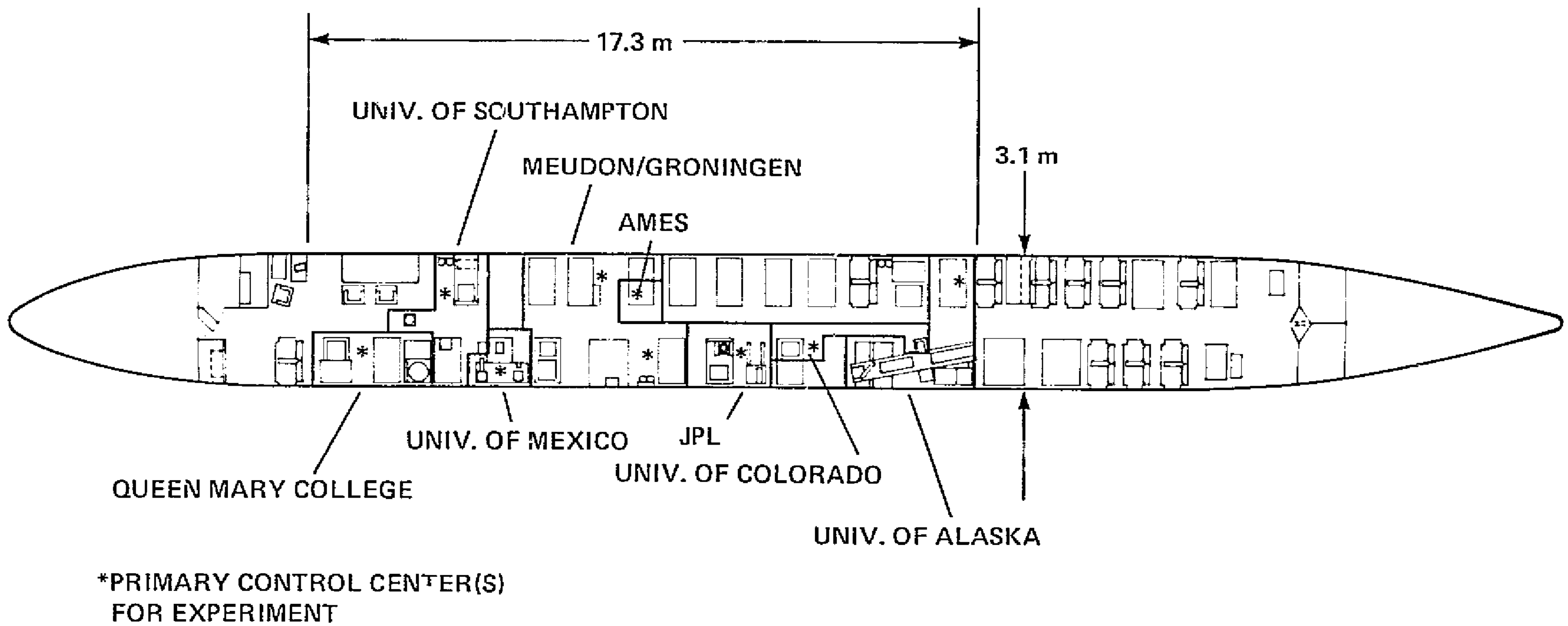


Figure 43.- Location of experiment control centers.

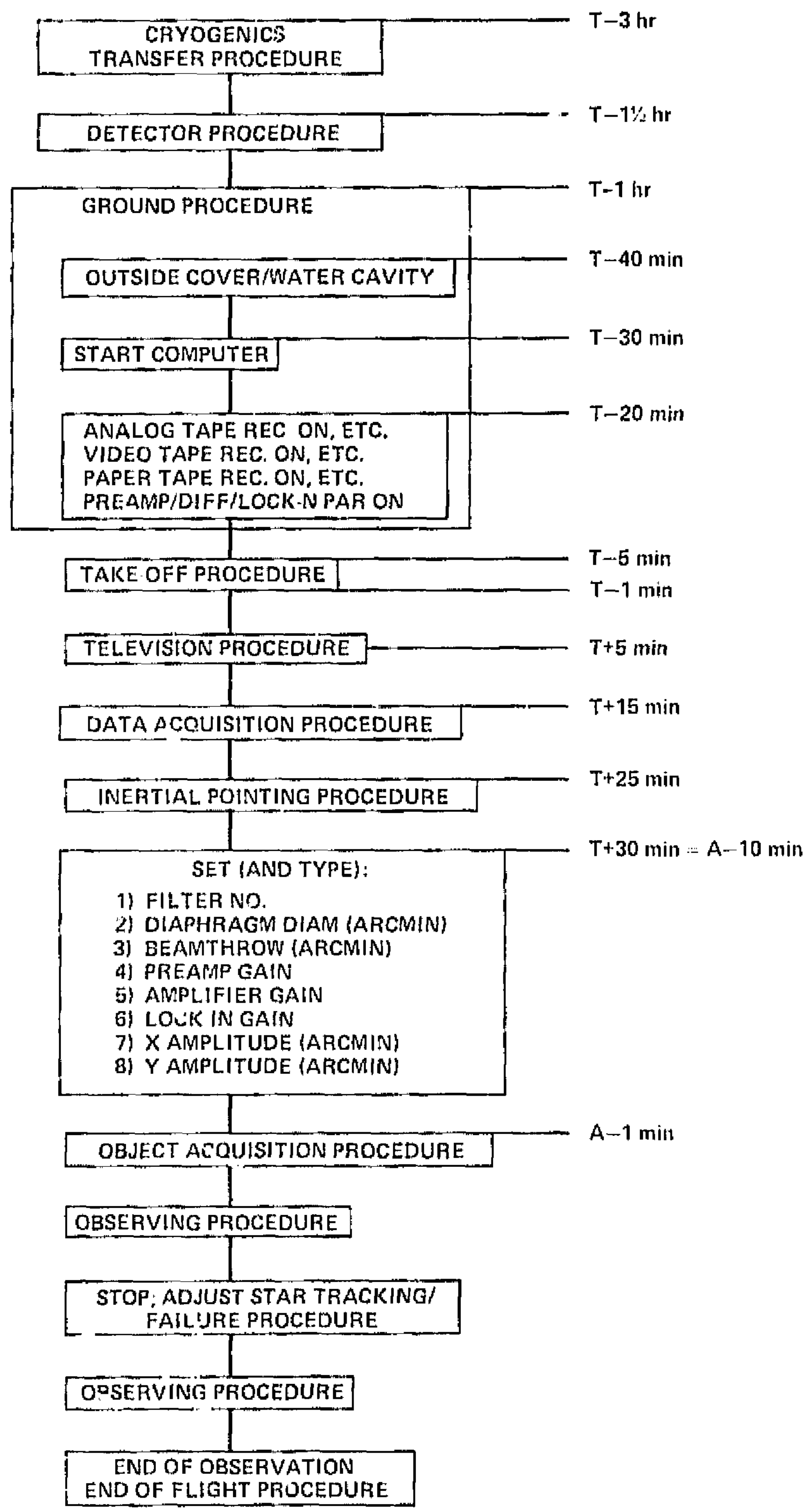


Figure 44.- Operations flow diagram for Meudon/Groningen experiment.

At the start of a data run the operator was first required to locate and lock onto the desired target, one of many objects in the field of view. This was an easy task with a bright target such as Venus, but it was more difficult with some of the other fainter and sometimes distributed targets. The tracking operation was often disrupted in actual flight by excessive roll of the aircraft, which caused the telescope to hit its limit stops and lose target lock. If the operator's attention was diverted for the moment, as by a filter adjustment, located on the rack behind his normal tracking position, the loss of target lock might go unnoticed for a minute or more. The operator then had to reacquire the target, lock it in, and reinitiate the computer program.

When computer-controlled, the telescope mapped an area of the sky. The maps were displayed at the computer terminal as a set of numbers (proportional to IR intensities). The EO made a hard copy of each display (using the ADDAS hard copy unit) for later PI perusal.

There usually was a transit leg between data legs during which the EO was not necessarily occupied. These legs varied in length, depending on target schedule, but rarely were longer than a few minutes.

Ames Research Center. Operational requirements were similar to those for the Groningen experiment as regards telescope guiding (described above), but differed in most other respects: There was no facility for computer control of the filter-wedge spectrometer, so the computer terminal was not activated. The Ames data were recorded by the ADDAS, so the video and Groningen tape recorders were not activated. Because of different densities and evaporation rates of the cryogenic fluids used (helium by Groningen and nitrogen by Ames), the Ames operator had to maintain the telescope in reasonable balance by adding incremental weights to the dewar as the flight progressed.

The Ames EO was provided with a preflight timeline, a list of operational procedures for equipment turn-on and data collection, a list of control settings during normal operations, and a brief list of possible problems and associated diagnostic procedures.

Queen Mary College/University of Southampton/University of New Mexico. These three experiments, located adjacent to one another in the front of the cabin, were operated by a single EO on all simulation flights. The QMC experiment could collect data at the highest ambient light level, so was put into operation first. The other two were then turned on, but remained in a standby mode for another half hour or more awaiting proper operating conditions. Once started, the New Mexico and Southampton experiments required only periodic monitoring and entries on log sheets from the EO. The EO thus spent most of his operating time on the QMC experiment, which required close attention at frequent intervals.

The QMC equipment was complex, operated at a very low signal level, and was subject to serious EMI from aircraft radio transmitters, a problem that was not identified during the presimulation flights. Thus, in addition to his other duties, the EO was asked to perform a diagnostic function - to identify the source of the "noise spikes" imposed on the primary signal channel and, if possible, take corrective action.

The experiment required detailed attention from the EO in taking interferograms, and close coordination with the ADDAS operator. The process of taking data involved mechanical travel of a mirror controlled by a lead screw. No limit switches were provided at the extremities of motion, and the mirror jammed if motion was not stopped in time. Since recording an interferogram took on the order of 10 min it was well that his other experiments required as little attention as they did. Despite the possibilities for error, both primary and secondary EOs were successful in obtaining a reasonable number of interferograms.

Only the 273 K reference body of the QMC experiment was used during the simulation week; the other 77 K reference was inactivated. This simplification was introduced so that the EO would not have cryogen-refill (LN_2) activities to contend with during flight.

The Southampton team did not develop integrated procedures for the three instruments that made up their experiment; three separate sets of detailed directions were furnished to the EOs. The separate instruments were: an all-sky camera at a zenith window, a photometer at a 65° elevation window, and a TV camera at a second 65° window. Each instrument required a number of operations to start data taking, but required only periodic checks once started. The TV system also required the reseating of an electronics card inside the camera case, which was loosened by the vibration of takeoff. Once this was done, the TV camera operated properly for the remainder of the flight.

No attempt had been made on this experiment to coordinate controls. The operator was required to operate separate controls for each piece of electronics equipment.

An abbreviated checklist for operation of the New Mexico experiment is shown in table 12. On a simulation flight, the EO was expected to fill out an expanded 6-page list, and there were 22 pages of informational material covering each item of equipment, its operation, and possible problems. The operator was required to mount the 16-mm camera after the start of each flight and to stow the camera before landing. Once everything was started on this experiment, no further attention was required of the operator except to make log entries each half hour.

Operation was simplified during the simulation week by leaving the two instruments, photometer and 35-mm camera/intensifier, in their normal position on the left side of the aircraft. Later on, the PI optimized data collection by switching these two instruments to the right side when conditions warranted.

Jet Propulsion Laboratory/University of Alaska/University of Colorado. Equipment for these three related experiments was located in the after portion of the aircraft cabin (fig. 35). A 35-cm telescope provided the main optical input to the Alaska and Colorado spectrometers, and a mirror was inserted at the telescope exit to switch from the Alaska to the Colorado instrument. When the Colorado spectrometer was receiving the telescope beam a second mirror was positioned in front of the entrance slit of the Alaska instrument so that the spectrometer received zenith light through a 65° elevation window. An Ames

TABLE 12.- SAMPLE CHECKLIST FOR EXPERIMENT OPERATION; UNIVERSITY OF NEW MEXICO

ABBREVIATED CHECKLIST

Date: ________________

Observer: ____________________________________

See detailed Checklist for Preflight and Postflight procedures.

WARM-UP (as soon as possible in flight)

- ____ Open plastic windows
- ____ Power on - high voltage power supply
- ____ Amplifier on
- ____ Recorder on - put date on chart
- ____ Image tube power on (first switch)
- ____ Mount movie camera; plug into 24-V transformer, secure air hose
- ____ Output on - high voltage power supply

START-UP (in dark skies, preferably during turn after Venus run)

- ____ Recorder: 1 min/in.
- ____ Remove signal cable, set zeroes, and record ranges
- ____ Lower pens
- ____ Replace signal cable
- ____ Activate photometer and filter wheel
- ____ Activate 35-mm image tube and camera (plug in motor-cam)
- ____ Activate 16-mm image tube and camera (check solenoid and motor shaft)
- ____ Set timer
- ____ Record sky condition (next sheet)

SHUT-DOWN

- ____ Amplifier
- ____ HV power supply off - output first, then power
- ____ Dark slides down; lens cap on (record on chart)
- ____ Image tube power supplies all off
- ____ Shut down movie camera, unplug from transformer and stow
- ____ Shut down 35-mm camera (unplug motor-cam timer)
- ____ Final WWV signal; chart to standby and OFF
- ____ All power off at overhead panel

technician operated a gyrostabilized mirror that intercepted the signal entering the cabin through a 14° elevation window. This mirror was considered experiment support equipment under the purview of the Mission Manager.

The EO operating the three combined experiments had to make adjustment or operate controls on the telescope mount, on an electronics rack across the aisle for Alaska, and at two other electronics racks for the JPL and Colorado experiments. Both the Colorado and Alaska experiments involved the use of interactive computer terminals. The fact that the keyboards of these two devices were not identical led to frequent operational errors by the EO as he moved from one to the other.

For safety reasons, the JPL TAOF was stowed during takeoff and landing, and the EO's first task was to mount the UV/TAOF on the telescope pointing out the 14° window. Most of the many JPL experiment controls remained in one position from flight to flight, and few had to be checked or reset. Once put into operation, the instrument swept repetitively through the UV spectrum with no attention from the EO. However, he was required to make a hard copy for quick-look information and for later PI perusal. This task, which was done fairly infrequently, involved the use of an X-Y recorder that required resetting after each sweep and a paper change after each two to three sweeps. Experiment parameters employed were hand logged on the X-Y plot.

Since all three of these experiments could start collecting data on the first data leg, the EO who ran them was extremely busy between takeoff and the first start point (30 to 40 min). The three experiments were activated roughly in parallel, with the experiment on the 35-cm telescope receiving slight priority. To accomplish turn-on in parallel, the EO spent short periods of time at each experiment, activating it a bit more with each visit. After the second simulation flight the rules were changed to allow the off-duty EO on any particular flight to aid the JPL/Alaska/Colorado EO by mounting the JPL UV/TAOF just after takeoff. This accommodation was, of course, peculiar to the aircraft simulation since in Spacelab such instruments would have to be set up only once.

For each experiment, the EO had available complete turn-on schedules and diagnostic suggestions for the more common problems. However, he did not have a priorities list that would tell how long to spend troubleshooting experiment A when experiments B and C were in need of his attention. This situation arose several times and was a considerable frustration.

Operation of the JPL experiment was considerably simplified during the simulation week by flying only the UV/TAOF. Omission of half the experiment was in part an effort to reduce the EO's combined workload to a reasonable level and also reflected the fact that, in any case, the visible/TAOF was achieving only marginal data quality.

The guide optics of the University of Alaska experiment were not mounted rigidly enough, and under various flight conditions (bumps, vibration, etc.), they often shifted out of alignment with the 35-cm telescope, thus presenting some problems in target acquisition. The EO acquired the target with the guide optics and then raster scanned the star-tracker optics until the latter "saw"

the target, at which point the system was switched to automatic guide. To determine when the tracker "saw" the target, the EO monitored its voltage output with a meter. Deflections were small and difficult to detect early in a flight when the sky was relatively bright. Acquisition of the first target in a flight frequently took 20 to 30 min. After acquiring the first target, the EO realigned the guide optics to facilitate the acquisition of subsequent targets.

Fortunately, other aspects of the Alaska experiment were less demanding of the EO's complete attention. Once on target, the spectrometer spectral sweep was activated, and data acquisition commenced using the computer terminal. Spectrometer sweep was cyclic and required no further attention from the EO except to alter operating parameters.

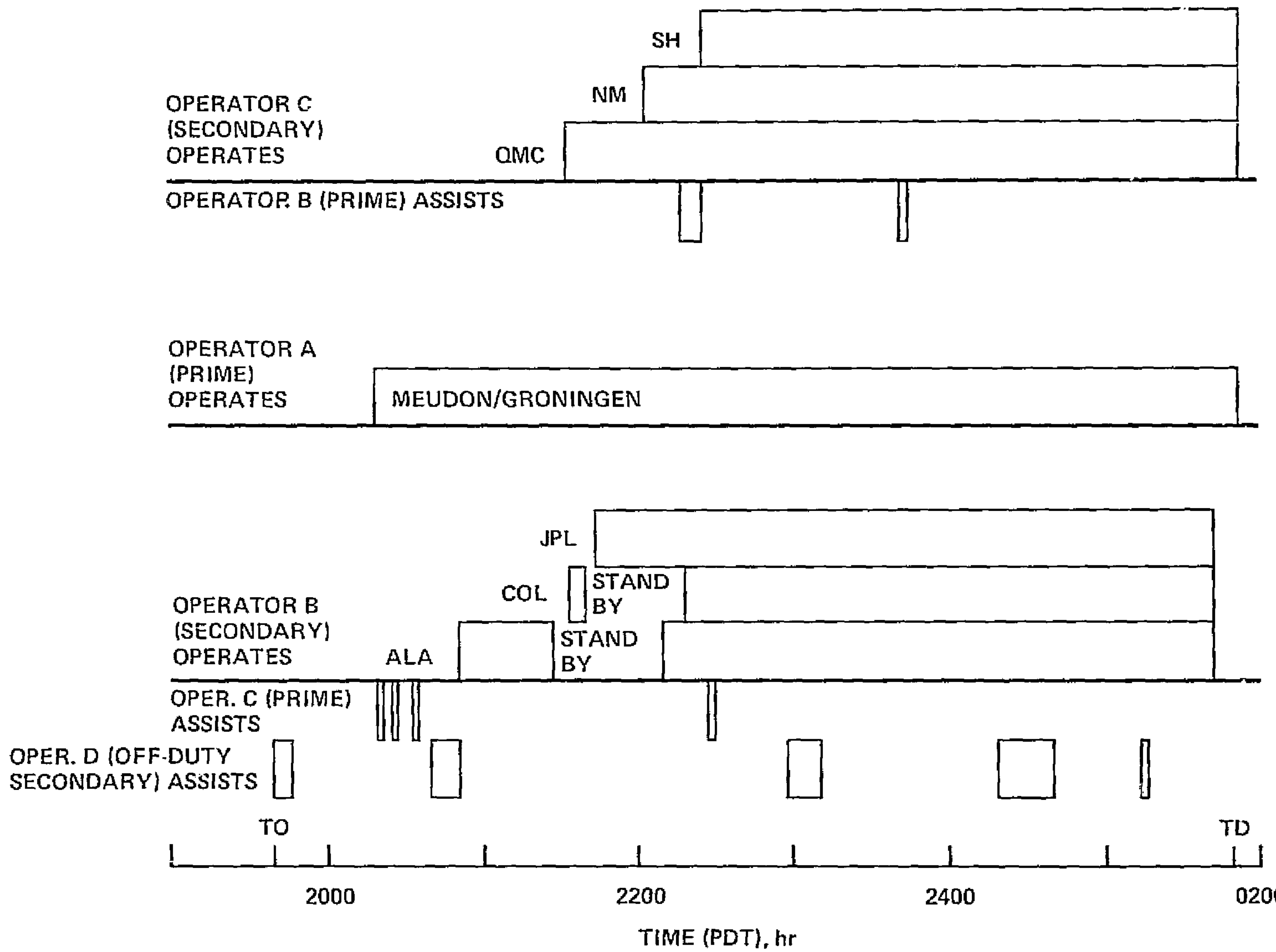
Spectra were summed and their average displayed on the computer terminal cathode-ray tube (CRT). The EO occasionally printed out a hard copy of these spectra (using the ADDAS hard-copy unit) for later PI perusal.

When the University of Colorado experiment was accepting signals from the 35-cm telescope, the activities discussed in the first paragraph of the previous section (Alaska) applied. If the telescope was on target, the beam could be switched to the Colorado spectrometer with no further adjustment of the telescope. As a prototype of an experiment designed to perform in space, the Colorado spectrometer was operated completely by remote control. All the EO had to do was to enter appropriate instructions at the computer terminal.

EO Interaction

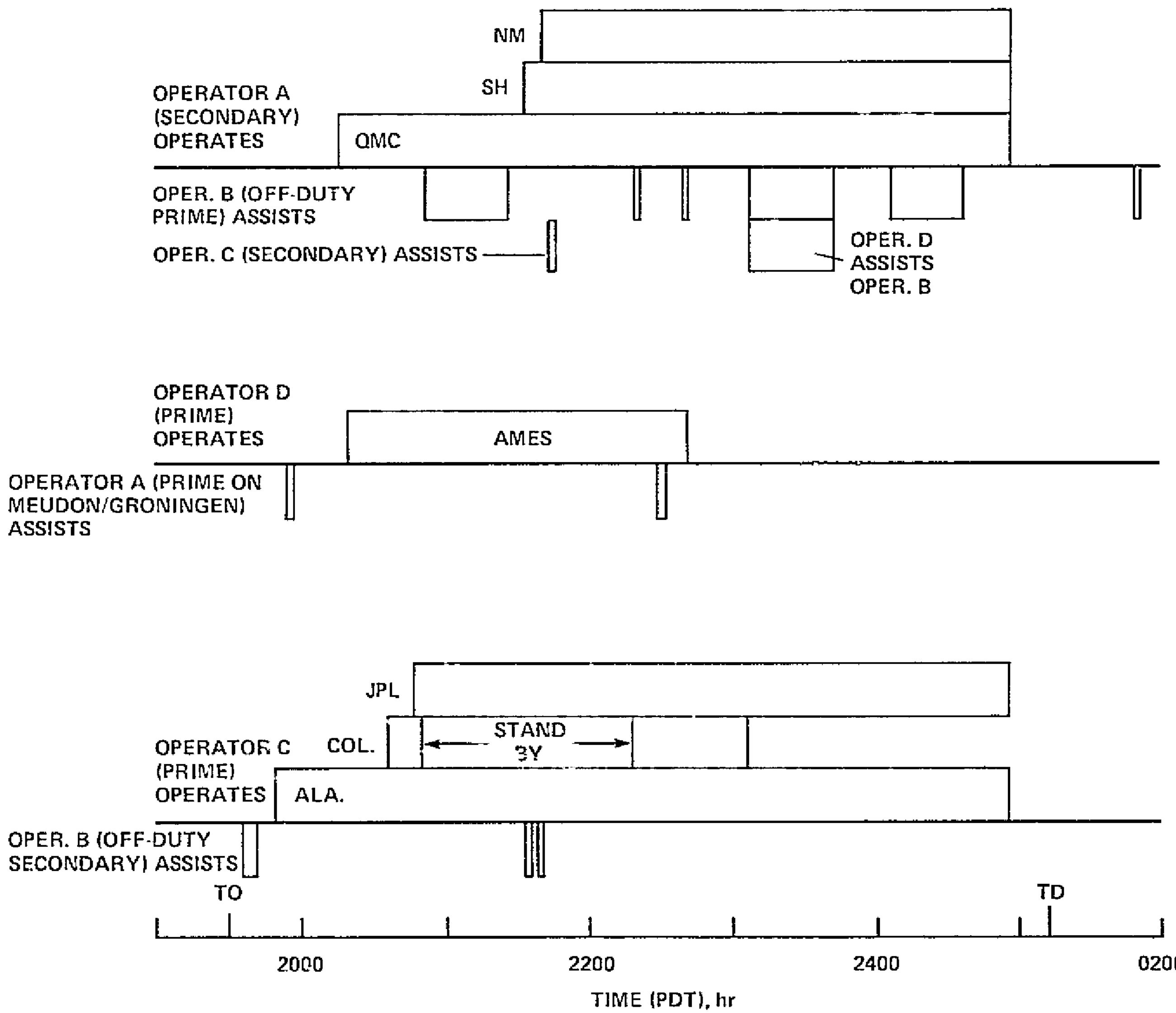
The plan to have only three EOs directly involved in experiment operation at any one time was largely successful. Interactions among active EOs were not precluded by mission guidelines, and a helpful interchange developed as the simulation progressed. On the other hand, interactions with the off-duty EO (except verbally) were at first prohibited and then later allowed, to the extent of simulating the 1-hour overlap planned for Spacelab.

During the first simulation flight, when each experiment was being operated by its primary EO, there was little need for EO consultation. On subsequent flights, however, when one or more experiments were being operated by secondary EOs, there was considerable interaction among all EOs, including the off-duty EO who had little else to do. Figure 45 gives timelines for EO interaction for flights 7 and 8 (third and fourth of the simulation flights), during which EO interaction was greatest. Blocks above the heavy line for each experiment (or group of experiments operated by a single operator) show total experiment operation time and the operator for that flight. Smaller blocks below the heavy line indicate assistance from another EO. For example, on flight 7, Operator B was operating the JPL/Alaska/Colorado experiment as his secondary experiment. However, he also spent some time interacting with Operator C who, as a secondary EO, was operating the experiment for which Operator B was the prime EO. On the same flight, Operator B received considerable assistance from Operator D, who was off-duty at the time. The extended interaction of Operator B as off-duty prime operator on flight 8 with Operator A



(a) Flight 7

Figure 45.- EO interactions in flight.



(b) Flight 8

Figure 45.- Concluded.

was largely an attempt to repair the QMC strip chart recorder. The EO interactions were primarily in the form of verbal exchanges of operational information. Actual physical adjustment of the experiments also accounted for considerable time, however, as indicated by the assistance provided the secondary EOs during experiment turn-on.

Overall EO Performance

EO performance during the simulation week was satisfactory. As might be expected, the major difference between EO and PI performance consisted in EO mental errors resulting from lack of familiarity and the tight timeline requirements for a single person operating several experiments. In some cases, the errors were serious (e.g., forgetting to turn on a camera during a complete flight, operating a tape recorder at the wrong speed for one hour, misjudging adequate signal-to-noise ratio, and forgetting to turn on high voltage for most of prime data leg); in others, there was little loss of data (e.g., keyboard errors when moving from one computer terminal to another with a slightly different key arrangement).

The EOs were resourceful in resolving problems encountered. Several times, strip chart recorders were patched from one experiment into another where a malfunction had occurred. Also, the QMC problem that had seriously degraded most data beginning with the first flight was correctly diagnosed by an EO as aircraft radio EMI. This diagnosis occurred in flight 8, but no solution was attempted until the resumption of PI flights since there was no shielding material available onboard.

Only two exceptions to mission ground rules were made during the simulation week, both with the approval of MPG representatives. The first corrected a deficiency in onboard spare parts. Four fuses were blown in a Groningen power supply at the end of flight 6 (the second of the simulation period). Since it was early in the simulation period and the power supply was vital to experiment operations, spares were obtained locally and given to the EOs. The second exception slightly revised the workload of one EO. After flight 6 it was decided that the off-duty EO would lighten the experiment turn-on burden of the JPL/Colorado/Alaska EO by mounting the JPL UV TAOF at the beginning of each flight. This decision was subsequently expanded to allow the off-duty EO to spend up to one hour assisting other EOs where needed, as noted earlier.

Postsimulation Flights

Following the simulation period, two weeks were allocated for further data flights during which the experiments were operated by the PIs under normal ASO operational procedures (no Mission Operations Center, Mission Manager sole authority for all flight and ground operations). Seven flights were conducted during this period.

During this period, EMI measurements on aircraft systems and experiments were carried out by ESTEC specialists, both on the ground and in flight. Although the initial proposal by ESTEC included extensive EMI surveys during

the experiment integration period, these had to be curtailed because of aircraft and experiment installation schedules. Had the earlier measurements been made, they would have benefited the PIs who were bothered by EMI; as it was, much valuable information was gained for Spacelab designers as well as for prospective users of the CV-990.

Except for two sections of daylight flight, the flight plans of the PI flights were basically the same as for the EO flights. However, the observational situation was deteriorating; Venus was getting too near the Sun and the Moon was setting too late, and both events degraded the data with excessive background light. For this reason, the Southampton and New Mexico PIs did not participate in all the data flights scheduled.

The daylight section of flight 15 was made for the purpose of optical detection of pollutant gases in the vicinity of Tuscon, Arizona. The astronomers were accommodated during this flight by landing at Tuscon and awaiting twilight, then flying the astronomical-object data legs. The first data leg of flight 16 was used to calibrate the effects of the earth's atmosphere using the Sun as a source of light.

Several experiments entered the PI flight phase with continuing problems: QMC had EMI from the aircraft radio; the Meudon telescope port was still covered with mylar, which degraded the data noticeably and also iced on the inside; and JPL had tracking, sensitivity, and EMI problems. Furthermore, the Colorado investigator was far from satisfied with his results using the Alaska telescope, and Southampton with their results at high elevation angle. QMC experimenters tried various shielding cages around their detector and preamplifier. All improved the situation somewhat, but none completely solved the problem. They stopped short of inserting RF filters in power cables.

The mylar icing problem was solved by directing a stream of warm air against the inner surface (flight 11). The window thickness was changed from 2 mil to 1 mil to reduce signal attenuation. However, the pressure differential caused this window to bulge out, so the 2-mil window was reinstalled. Ames engineers designed a new aerodynamic fence to replace the Meudon configuration (flown successfully on a forward window of a French Caravelle). On flight 16, the telescope performed well with the new fence and without the mylar window.

The JPL PI installed a stabilized mirror in front of his 14° window telescope before the first PI flight (flight 10). The mirror greatly improved his guiding ability, but consistent guiding on an astronomical object still required constant effort by an operator. Automatic guiding remained impossible. The sensitivity and EMI problems encountered by the JPL TAOFs were not adequately resolved during the course of the PI flights. In this case, new instrumentation was put to use in the field before its limitations and operational requirements were fully understood.

Colorado joined JPL in adapting to the new telescope/mirror arrangement (fig. 28) and worked out a time-sharing plan for best use of observing time. The Southampton group moved their TV camera to a low-boy rack for viewing through a 14° elevation window, the same as New Mexico (fig. 46).

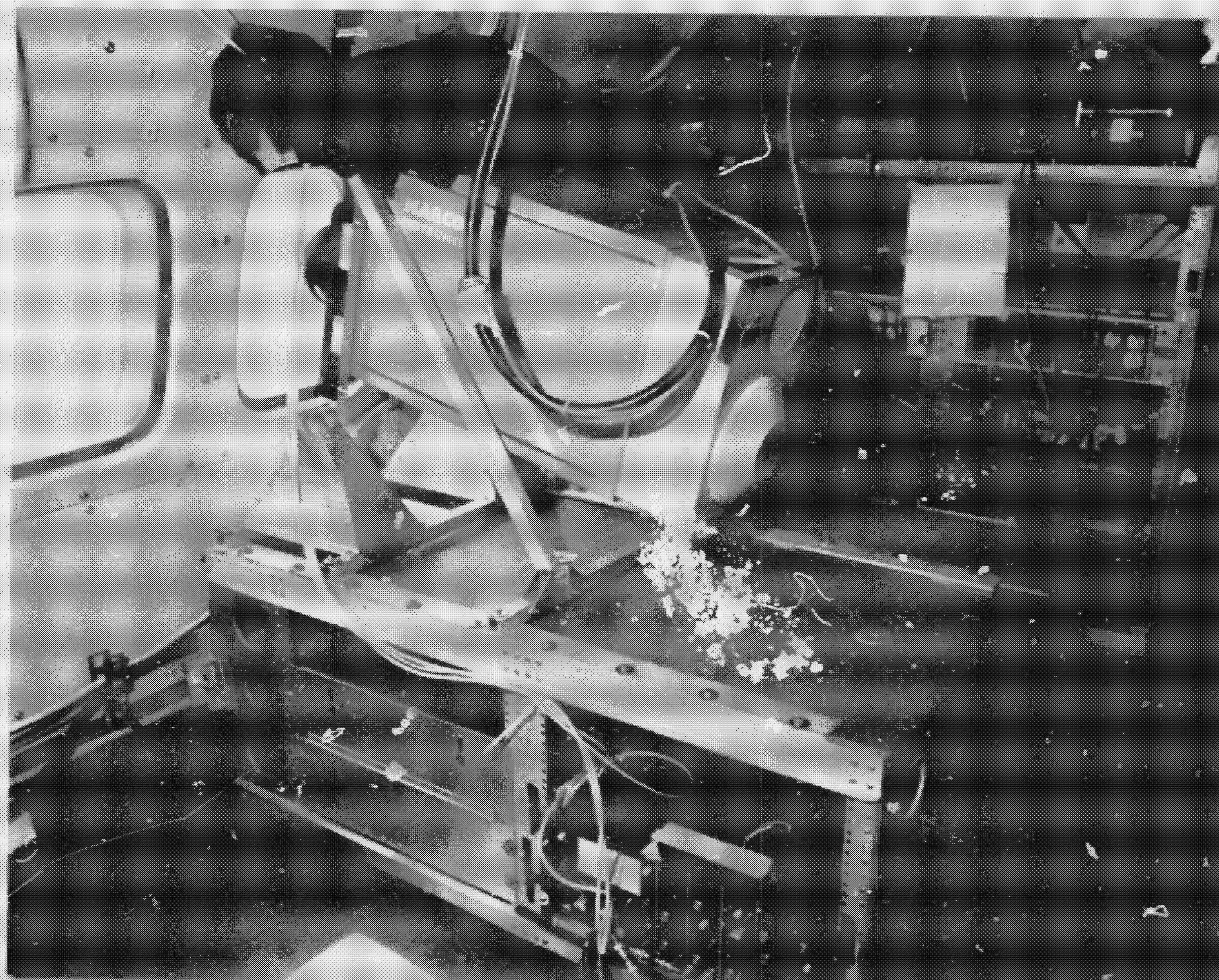


Figure 46.- Southampton TV camera mounted at 14° elevation window.

REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR

All EOs except one (who had other commitments) were aboard during two of the PI flights. One was aboard on flights 11 and 16, and two on flights 12 and 15. The EOs played active roles, participating directly in the operation of what had been their prime experiment. EO participation in PI flights was not planned. It came about primarily because of EO interest in making a further contribution to the mission.

MISSION RESULTS

This section treats some of the more significant results of the Joint ASSESS Mission: the performance of the EOs in their assigned duties, their response to equipment malfunctions, and their scientific accomplishments. Baseline comparisons with postsimulation PI data flights have been evaluated to establish the relative effectiveness of EO and PI research operations. Attention is also given to performance of aircraft subsystems and their impact on experiment performance, as well as to management performance in support of mission goals.

Experiment Operator Performance

General Remarks

The primary objective of this mission was to test the concept of proxy operation of experiments by PI-trained EOs. This concept has been tested once before in an ASSESS Spacelab simulation study using a Lear Jet aircraft with a single experiment (ref. 10). During that Lear mission, two EOs operated an IR astronomy experiment on nine flights over a 5-day period with reasonable success. For the Joint ASSESS Mission, each EO operated one complex experiment or several simpler ones simultaneously. Mission results demonstrated the basic validity of this extension of the EO concept. Although kept extremely busy during the simulation flights, the EOs managed to keep all experiments in operation as required by the PIs' respective observation plans.

This match of operation plan to available EO time was not a chance occurrence, but rather evolved during final preparations of the mission. From the beginning of the program it was intended that EO assignments be demanding enough to permit a realistic evaluation of their capabilities. Thus, each experiment had sufficient options for nearly full-time use by at least one operator, and as flight time approached certain simplifications were necessary to achieve a realistic EO workload. For this reason, as expected, there were some concessions made to facilitate EO operation of the two complex experiment groups. In each three-experiment group, two of the investigators reduced the number of operating options in their experiments to achieve a balanced time sharing for the group. Thus, New Mexico limited operations to one position on the left side of the cabin, while QMC used only one of the two temperature references available in the experiment. In the other group, JPL operated only one of the TAOF spectrometers and reduced the number of control adjustments on that unit, while Colorado deleted the option for inflight data processing and

analysis. With these modifications worked out by the PIs and EOs, the other two experiments, Southampton and Alaska, could function fully as planned. Neither Meudon/Groningen nor Ames made any concessions to simplify EO tasks.

Because the EO training was not as thorough as it might have been, the simulation got off to an uncertain start with the EOs lacking full confidence in their ability to operate assigned experiments. All of the EOs had extensive prior experience with electronic instrumentation, however, and three had previously flown with experiments, so they were able to adapt to the situation. As the simulation week progressed, operating confidence developed rapidly with a concomitant increase in performance level. Even so, the EOs felt that their performance was still improving by the end of the simulation period. Objectively, improved EOs performance also was apparent in their growing, but never complete, independence from detailed checklists to guide experiment operations.

The EOs provided assistance to one another across experiment lines, which was made possible by cross-training. Most often it was the off-duty prime operator who advised or assisted his backup, secondary operator in flight. In contrast, the PIs seldom sought counsel from their peers during the postsimulation flights, and when they did it usually was in connection with a common problem of the environment such as EMI, vibration, or background noise from other sources. The assistance times of the off-duty EO were generally of short duration and in aggregate were tacitly assumed to represent the shift overlap period planned for Spacelab. One primary difference, of course, was their occurrence at intervals over the data-acquisition period for troubleshooting problems or relieving peak workloads. As evidence of a growing teamwork among all the EOs, the frequency of such events increased to about 2 to 3 an hour, overall. In line with the mission guidelines, nevertheless, these interchanges seldom exceeded a few minutes.

Overall Use of Time

Table 13 summarizes the overall distribution of EO time from the start of the mission at 1300 hr (local time) on June 2 until landing after the fifth flight at 2300 hr on June 7. The total simulation period was 130 hr. Times have been divided to show ground and flight activities separately. Estimated flight times are based on the Moffett-Moffett takeoff and landing times. Thus, the 31.7 hr total includes 4.6 hr spent on the ground at Las Vegas because of engine trouble during the first flight. EO activities have been broken down into experiment-related tasks and personal activities. Subdivisions of these are: brief/debrief (formal meetings between MOC personnel and simulation crew), PI/EO consult (individual conversations between PIs and EOs), EO assist (direct verbal or physical assistance given by one EO to another), routine servicing (cryogenic servicing, changing batteries, operational checks), maintenance (diagnostic and repair efforts), eat/sleep (time for flight lunch not included), operation (experiment turn-on and data collection), and other (personal hygiene, off-duty, free time). EO times were recorded by personal observation, with the direct record augmented by communication system recordings and MOC log book entries.

There are obvious reasons for time differences among the EOs. In the "flight" category, Operator D operated experiments on only three (instead of

TABLE 13.- DISTRIBUTION OF EO TIME DURING SIMULATION PERIOD

	Total simulation time = 130 hours										
	Ground time = 98.3 hours							Flight time = 31.7 hours			
	Experiment tasks, %					Personal activities, %		Experiment tasks, %			Personal activities, %
EO	Brief/ debrief	Consult PI/EO	Assist EO/EO	Routine service	Mainten- ance	Eat/ sleep	Other	Operate	Service/ mainten.	Assist EO/EO	Other[2]
A	5.4	4.1 (8.[illegible])[1]	0.7	28.5	0.9	43.1	17.3	48.6	7.3	2.5	42.3
B	5.4	3.7 (7.6)[1]	1.2	30.8	0.7	43.1	15.1	58.4	2.2	6.9	31.5
C	5.4	3.4 (7.0)[1]	1.7	22.5	2.6	43.1	21.3	56.5	2.2	2.5	38.8
D	5.4	2.5 (5.3)[1]	2.7	24.1	7.1	43.1	15.1	29.7	9.8	6.6	54.3
Average	39.7%					60.3%		58.3%			41.7%

[1]Percent of work time; [i.e., total - (eat/sleep + brief/debrief)]

[2]Includes off-duty time

four) flights, and took the opportunity on his two off-duty nights to diagnose instrumentation problems with his prime experiment. Operator A put in over 2 hr in diagnostic efforts during the third simulation flight, while both Operators B and D gave generously of their time to assist other EOs. In the "ground" time category, Operators A and B were involved in considerably more cryogenic servicing than the other EOs. Operator D was the only EO to remain aboard the aircraft during an engine run-up and refuel period (2 hr), attempting to diagnose an equipment problem.

The time spent in PI/EO consultation during the simulation period seems surprisingly small (only 3 to 4 percent in table 13) since the microphone apparently was in use almost continuously. However, the data show that calls were frequent (as many as eight in a day between the same PI and EO), but short (usually less than 4 minutes in length). The number of contacts doubled after the first day and remained roughly constant at about 30 throughout the simulation period. The total amount of time per day spent by all EOs in PI consultation similarly increased from 1 hr on the first day to about 2-1/2 hr thereafter, as mission activities settled into a routine.

An overview of the simulation period shows that an average of 40 percent of the ground time and almost 60 percent of the flight time was spent on experiment tasks (table 13). The average EO day was divided as follows:

Experiment tasks	10-1/2 hr
Off-duty time in flight	2-1/2 hr
Life support functions	8 hr
Free time (distributed)	3 hr

This balance of activity appeared suitable for even longer periods than the 5-1/2 days of the Joint Mission. After the first two days of familiarization, the EOs settled into a routine that allowed more free time. Also, the off-duty flight gave each EO a rest from the set routine for part of one day, an opportunity not available to the Mission Manager.

It should not be overlooked that on a standard day the EO worked perhaps an hour or two longer than the average of 10-1/2 hr shown above, both in experiment preparation on the ground and operation in flight, with correspondingly less discretionary time available. As the Mission Manager observed, the EOs seldom were without some experiment-related task to perform, except when sleeping.

Operational Effectiveness and Data Quality

Table 14 summarizes EO performance in flight during the simulation period in terms of time effectiveness and data quality. Time effectiveness is expressed as percent of available time (time on track) that the experiment was operated to acquire data, and data quality is based on PI estimates made at the end of the simulation period using the rating scale shown in the table. It is immediately apparent that results were better for all-sky observations than for astronomical targets involving acquisition and guiding functions, and depending

TABLE 14.- EO INFLIGHT PERFORMANCE RATINGS

	Number of observation periods		Percent of available time utilized			Data quality estimates (PI)*				
						Type of observation		Average of all observation periods	Type of operation	
EO	Astron. targets	All-sky	All	Astron. targets	All-sky	Astron. targets	All-sky		Normal	Equipment problems
A	9	3	80	75	95	1.4	3.3	1.9	4.0	1.5
B	2	14	77	65	79	2.5	3.0	2.9	2.9	2.5
C	6	12	74	40	91	1.8	2.2	2.1	2.4	0.5
D	7	3	54	40	85	1.7	1.5	1.7	1.9	1.2
All	24	32	73	56	86	1.7	2.5	2.3		

*Data quality scale applied to PI estimates:

4 = Excellent	11 times
3 = Good	11 times
2 = Fair	18 times
1 = Poor	10 times
0 = No data	6 times

on aircraft position and stability. Thus, EOs whose major assignment was astronomy usually scored lower than those making all-sky observations. When equipment was operating normally, the EOs produced average or better data; when problems occurred, the quality of their product dropped sharply. Overall, the results are distinctly favorable; experiments were maintained in operable condition to produce useful quality data for nearly three-fourths of the time available to the EOs.

Comparison of EO and PI Operating Performance

Differing modes of operation were employed on EO and PI data flights. During the PI flights, there was a large increase in manpower (from 3 to 14) that allowed operator specialization, and the experimenters had free access to equipment and outside support. In addition, significant improvements were made on six of the eight experiments to improve data acquisition and quality. In combination these factors should have created near optimum operating condition for the PIs, within the normal constraints of airborne research, during the seven postsimulation flights. The following comparisons are made with this in mind.

Table 15 gives manpower loading, observation time, and data quality by individual experiment for both flight periods. Data quality is based on PI estimates rated on the 0 to 4 scale. Overall, the results for EO and PI operation are quite comparable, in itself sufficient reason to commend the EOs' performance. There are some other notable factors that require attention, however. First, during the PI flights, there was a substantial calibration effort for four experiments, as opposed to a modest effort for only one during the simulation period. This effort combined with actual observation times gives seven of the eight experiments a significantly longer period of PI operation, clearly a reflection of the greater manpower loading. On the other hand, data quality is not as favorably inclined toward the PIs. Of the three apparently significant improvements in data quality achieved by the PIs, two (Meudon and Colorado) were influenced strongly by experiment changes that would have similarly benefited the EOs. Of the remaining five experiments, three achieved slightly better data quality and two (New Mexico and Southampton) suffered some reduction in quality due to sky brightness from various sources (e.g., the Moon) that interferred with their observations.

The overall comparison at the bottom of table 15 shows PI performance some 30 percent better in operating time and 20 percent in data quality, but about the same in utilization of available observing time. If the PIs were operating at near peak effectiveness for the given conditions, then the EOs were able to achieve about three fourths this level with less than one fourth the manpower. Without question, this was an outstanding accomplishment.

To further clarify the relative performance of the two groups, table 16 ranks experiments in order of improvement on PI flights and indicates the primary reasons for the observed differences. Results are given in terms of observation time and data quality. Again, manpower loading and equipment changes account for the longer time periods and better data quality, respectively.

REPRODUCIBILITY OF THE

TABLE 15.- COMPARISON OF EO AND PI PERFORMANCE

Experiment	Operator	Average manpower loading	Target observation time per flight (avg)*		Data quality estimates (PI)		Calibration time per flight, minutes
			Minutes	Percent of available	No. obser. periods	Overall rating	
Meudon/ Groningen	EO (P)	1	155	72	9	1.4	6
	PI	3-1/2	121	77	14	2.9	79
Queen Mary College	EO (P)	1/3	80	47	3	2.7	0
	EO (S)	1/3	185	74	2	2.5	0
	PI	1-3/4	222	66	7	2.6	29
Southampton	EO (P)	1/3	200	100	3	4.0	0
	EO (S)	1/3	240	89	2	4.0	0
	PI	1-3/4	218	99	6	2.8	4
Ames	EO (P)	1	59	48	5	1.7	0
	PI	3	60	48	2	2.0	38
JPL	EO (P)	1/3	190	100	3	0.5	0
	EO (S)	1/3	233	93	2	1.5	0
	PI	2	215	63	9	1.0	39
Alaska	EO (P)	1/3	190	92	7	2.1	0
	EO (S)	1/3	233	93	6	1.7	0
	PI	1-3/4	278	87	13	3.5	6
Colorado	EO (P)	1/3	39	44	5	2.0	0
	EO (S)	1/3	104	65	4	1.8	0
	PI	1	109	33	16	3.4	0
New Mexico	EO (P)	1/3	158	90	3	4.0	0
	EO (S)	1/3	193	98	2	4.0	0
	PI	2	263	100	5	3.8	0

*Not including calibration periods.
(P) Primary assignment
(S) Secondary assignment
Overall ratios:

- Manpower loading, PI/EO = 14/3 = 4.7
- Operating time (incl. calib.)/expmt. flight, PI/EO = 205/158 = 1.3
- Utilization available observing time/expmt. flight, PI/EO = 0.74/0.76 ≈ 1.0
- Data quality rating/expmt. obsv. period, PI/EO = 2.8/2.4 = 1.2

TABLE 16.- RATIOS OF PI TO EO PERFORMANCE BY ORDER OF IMPROVEMENT

Experiment	Ratio of observing times, PI/EO, per flight	Primary reasons for change in performance
QMC (1)	1.81	Full attention of PI
Colorado (2)	1.60	Full attention of co-investigator; no time sharing of Alaska telescope
UNM (1)	1.52	PI observations both sides of aircraft, so more time available
Alaska (2)	1.34	No time sharing with Colorado; full attention of co-investigator
JPL (2)	1.04	Automated skyglow measurements for both EOs and PIs
Ames	1.02	Limited PI experience with system; some calibration
Southampton (1)	1.01	Experiment required little attention
Meudon/Groningen	0.78	Extensive calibrations by PI
Group (1) average	1.45	Available manpower
Group (2) average	1.33	No time-sharing manpower or equipment
Single experiments average	0.90	Calibration requirements

(a) Observing time.

Experiment	Ratio of data quality, PI/EO, all observations	Primary reasons for change in performance
Meudon/Groningen	2.07	Increased signal strength
Alaska (2)	1.84	Automated skyglow measurements (PI)
Colorado (2)	1.79	Much improved optics for co-investigator
Ames	1.19	Experienced telescope operator (Meudon); increased signal strength
JPL (2)	1.11	Greater experience of PI with unproven instruments
QMC (1)	1.00	RFI and ADDAS problems for both EOs and PIs
UNM (1)	0.95	High-quality data for both
Southampton (1)	0.70	Reduced by sky brightness for PI
Group (1) average	0.88	Environment and support problems
Group (2) average	1.58	Improved input signal
Single experiments average	1.63	Improved input signal

(b) Data quality.

Response to Inflight Problems and Experiment Malfunctions

EO response to experiment and environmental problems is a primary element in the total performance equation. The capability to evaluate and resolve problems will be vital to the success of a Spacelab mission, as it was to the Joint ASSESS Mission. In this respect, the present experience was a realistic analog. Both the physical isolation and the means of communication were designed to duplicate the essential constraints of Spacelab.

Problems encountered and EO responses are summarized in table 17. Only the overall trends are discussed here. Appendix A provides more descriptive information and analysis. Sixty-nine events were identified (table 17), of which almost three fourths were in the experiment, less than one fourth were caused by the operator, and the remainder by the vehicle and/or its support systems (GFE). More than two thirds occurred while an EO was operating his primary experiment. Corrective measures resolved 29 problems during flight, 10 of which involved assistance from another EO or the Mission Manager. In another 25 cases, the EO took positive action to troubleshoot the malfunction or to adjust his procedures to "live with" it. Only 15 problems were deferred for resolution after flight, and of these there were only two that caused experiment operations to cease (one each on Ames and Colorado).

Table 18 compares the frequency and resolution of only experiment malfunctions for the simulation and postsimulation periods. The total number was similar for both periods, but during the PT flights, over two thirds of the malfunctions were concentrated in the QMC and JPL experiments (RFI was a major problem for both, as it had been earlier). The primary message of table 18 is that the EOs were able to solve a larger number and proportion of problems than the PIs, most notably in flight without PI support. Some of the more serious problems required assistance from the PIs after flight, but postflight aid of this kind was an accepted mission guideline and does not detract from EO performance. In addition to the EOs' competent handling of normal experiment operations, they also responded effectively, by PI standards, to equipment malfunctions. It should be noted, however, that both EOs and PIs were unable to solve a substantial number of problems. In a few cases, the impact of these unresolved problems on scientific accomplishment was significant, indicating the need for a more positive input by management to the experiment development process.

Scientific Results

Final assessment of scientific results achieved by the various experimenters must await detailed study and interpretation of the data. A tentative assessment of the results was obtained through interviews with each PI following the mission and such preliminary analytical information as the investigators could provide in time for inclusion in this report.

TABLE 17.- PROBLEMS IMPACTING EXPERIMENT OPERATION DURING SIMULATION FLIGHTS

EO	Primary or Secondary	Source and Number			EO Responses				
					Corrected in Flight		Other Actions		
		Expmt.	GFE	Operators	Self	With help	Live with	Troubleshoot	Fix on ground
Operator A	P	6	0	3	0	0	5	3	1
	S	2	0	0	0	1	0	1	0
Operator B	P	14	1	1	6	1	1	3	5
	S	4	1	2	1	4	1	0	1
Operator C	P	11	3	2	7	3	4	0	2
	S	6	0	1	3	1	0	1	2
Operator D	P	3	2	1	0	0	6	0	0
	S	3	0	3	2	0	0	0	4
All	P	34	6	7	13	4	16	6	8
	S	15	1	6	6	6	1	2	7
	All	49	7	13	19	10	17	8	15
	%	71	10	19	28	14	25	11	22
		100%			42%		58%		

REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR

TABLE 18.- MALFUNCTIONS OF EXPERIMENT EQUIPMENT

Experiment	Number of malfunctions		Problem solved				EO required assistance	Problem not solved	
			In flight		On ground				
	Simulation flights	Postsimulation flights	By EO	By PI	By EO	By PI		By EO	By PI
Meudon/ Groningen	4	1	0	0	1	1	0	3	0
QMC	15	16	7	3	2	5	3	6	8
Southampton	4	3	2	0	2	3	1	0	0
Ames	2	1	1	0	0	0	0	1	1
JPL	4	16	0	1	0	1	0	4	14
Alaska	8	3	4	3	3	0	2	1	0
Colorado	11	2	7	2	3	0	3	1	0
UNM	1	3	1	3	0	0	0	0	0
All	49	45	22	12	11	10	9	16	23
Percent	100	100	45	27	22	22	18	33	51

Meudon/Groningen

The Meudon/Groningen experiment yielded four types of information:

1. Observations of hitherto unmapped IR sources, which have produced original data (e.g., observations of the HII region near ρ Ophuichi and the star S Cephei, mostly during the PI data flights following the simulation period).

2. Observations of previously mapped sources, which have augmented the quantity of extant data. For example, observations of M-17 both during and after the simulation period have about doubled the infrared data available.

3. Noise (sky signal) measurements of the entire airborne system, including the effect on noise levels of such parameters as diaphragm diameter, altitude, RFI, atmospheric turbulence, and wavelength (mostly during PI data flights).

4. Observations of Venus that were used for calibration.

Data interpretation was significantly impeded by the presence of background sky signal, which masked that from the target. Much relevant information on "sky noise" was obtained. Signal strength, particularly at altitudes below the tropopause, was found to be much greater than that measured under laboratory conditions. Unfortunately, at the latitudes required to observe the PI's selected targets, as determined by the limited range of telescope elevation angle, the tropopause was often higher than the ceiling altitude of the aircraft. Computer analysis to isolate the target signal from the background is being done by the Meudon principal investigator at his laboratory; such involved processing was not possible at Ames. It appears that the atmosphere is not very transparent in the wavelengths of interest, and the data obtained on NGC-7000, M-17, and ρ Ophiuchi are not yet explicable.

The EO's contribution to the scientific results from this experiment was significant: Over one third of the total observation time was achieved during EO operation. An equipment limitation beyind his control (the frosted mylar port window) detracted from the quality of some of his records, but otherwise his results compared favorably with the PI's on similar targets.

Queen Mary College

Among the goals attempted for ASSESS was an improvement in the technique for measuring atmospheric infrared emission that would permit identification of minor atmospheric components, many of which have rich spectra. This required a trade-off between high-resolution separation and the requisite time to generate an interferogram. Unlike the integrating spectrometer, which scans only one frequency at a time, the interferometer examines essentially all the frequencies simultaneously, yielding a higher signal-to-noise ratio. Specifically, the goals were:

1. To obtain line spectra with five times the frequency resolution previously obtained.

2. To obtain the line spectra in one-half the time previously required.

3. To identify the atmospheric components that generate the line spectra.

After a number of obstacles were overcome, the first two goals were achieved, and the status of the third will be known when data processing and analysis are completed. Although it was never intended to process all the data in the computation center at Ames, it was necessary to process those from early flights to improve and ultimately optimize the system parameters for subsequent flights.

The data processing was complex and required real-time interactions with the computer to achieve results, in part because of unexpected RFI spikes (from the CV-990 VHF system) on the data tape that either seriously distorted the output or stopped the processing. Some 20 to 40 interferograms were generated each flight, requiring 10 min of computer time per interferogram. Adequate and timely processing was difficult, however, because access to the Ames 360 computer was limited to the midnight to 8 a.m. shift, when both the PI and the ASO programmer had to be present for immediate postflight processing.

The technique for measuring infrared emission was proved valid during EO operations when many spectral lines with good signal-to-noise ratios were acquired. Further data acquisition to obtain thermal atmospheric emission versus wavelength calibrations was planned and carried out in the postsimulation period (the calibration data had been eliminated to simplify EO procedure), and subsequent data analysis at the PI's home base will permit source identification. The EOs made a significant contribution to the total of scientific results for the mission, although they had to operate two other experiments as well. Their task was unduly complicated by the erratic behavior of the system, later identified as RFI. Over one-fourth of the interferograms were recorded during the simulation period, with a fivefold rise in output as the EOs became more adept at operations. Data quality was comparable to that obtained later by the PI.

University of Southampton

Data on OH clouds were recorded at two different elevation angles (14° and 60°). Data at the lower angle correlated well with those taken by New Mexico (at 9°). A trial of the TV equipment in recording meteors was not entirely successful because of image degradation due to aircraft roll.

Southampton looked initially at high elevation angles (60°). While a relatively undifferentiated haze could be detected using long integration times, it was not possible to see distinctive airglow features at the 60° elevation angle. Consequently, an auxiliary meteor viewing experiment was conducted, which resulted in a fairly large number (about one every two minutes) of meteor detections on one flight due to the capacity of the intensified TV camera to detect bodies of the seventh magnitude. However, viewing times were neither as long as desired nor in the most appropriate quandrant because of the priority given other experiments.

Subsequently, during the final two weeks of the mission, Southampton investigators made use of a 14° elevation window and were gratified to see an enormous amount of OH airglow structure. The PI believes that the difference between results at 60° and 14° cannot be explained by horizontally stratified regions, but that the regions may contain wedge-shaped strata instead. Analysis of the tapes at the experimenter's home base will permit more thorough study of the data on meteors (there are about six frames per meteor) and on the distribution and geometry of the airglow regions.

The EOs made a significant contribution to the scientific results from this experiment. Again, the equipment was well automated for continuous operation with little attention. More than one-third of the total record was made during EO operation, with a quality comparable to that of the PI team. Although these data were recorded at 60° elevation angle (as directed by the PI) and, for the reasons given, do not reveal the detailed structure expected, they nevertheless provide important evidence to aid the understanding of OH cloud physics.

Ames Research Center

During the relatively brief period in which the Ames experiment made use of the Meudon telescope aboard the CV-990, IR observations were carried out on Venus, α Herculis, and IRC 10216. The Moon was also observed for calibration. During each flight on which the Ames experiment was operated, at least a quarter hour of continuous Venus data was obtained. However, the data are accompanied by considerable spectral noise and an offset due to the mylar window over the telescope port. The mylar not only reduced the spectral response range of the detector from its normal 3-6 μm to 3.7-5.2 μm but also introduced an offset that was an order of magnitude greater than the signal level. It should be possible to average the noise and compensate for the offset to obtain useful data on Venus. Despite the attenuation of the signal by the mylar cover, the absorption lines of this material have been used to provide an accurate calibration of the filter wheel.

There were problems on the flight in which α Herculis and IRC 10216, and α Virginis were targets: Considerable roll occurred, apparently due to a minor maladjustment in the aircraft autopilot. It was not possible to acquire either α Herculis or α Virginis long enough to obtain useful data. The attitude was stabilized at the time IRC 10216 was acquired, and it is believed that the observations will yield good original data.

EO observations were the major scientific return from this experiment. The only data on IRC 10216 and fully three-fourths of the Venus data were collected during the simulation period.

Jet Propulsion Laboratory/Alaska/Colorado

Jet Propulsion Laboratory. Data obtained with the UV TAOF appeared of marginal quality, even though a stabilized mirror was introduced into the optical system after the simulation period to allow more consistent guiding on

astronomical objects. This instrument was delivered so late that it received no laboratory checkout, so reasons for the lack of sensitivity are not understood.

The visible range TAOF, operated only during the PI flights, recorded spectroscopic data on twilight airglow, the Moon and some night airglow in the range from 430 to 600 nm. This experiment suffered from a high background noise level and EMI, so the taped data will have to undergo computer analysis before yielding true spectral information.

Over three-fourths of the operating time on the UV system was accumulated by the EOs, and data quality was comparable to PI results. To the extent that these data can be used, either as science or as a base for instrument improvements, the EO contribution is of a significant value.

University of Alaska. About 2-1/2 hr of Venus spectral data have been obtained, which will be normalized using solar data obtained on the single day flight of the mission. This information will then be analyzed for constituents of the atmosphere of Venus, for example, SO_2 and NH.

Some terrestrial airglow (O_2 Herzberg and OH Meinel) data were obtained. After noise filtering, these are expected to yield information on airglow temperature and intensity as a function of position. This information will then be compared with theoretical calculations of band shape as a function of temperature.

In addition, sufficient information was acquired during twilight observations to deduce O_3 densities in the Earth's atmosphere. These data will be used to deduce the total ozone content as a function of altitude for various solar depression angles. This will yield atmospheric transmission in the ultraviolet region. A few spectra of atomic oxygen lines have been obtained for reference use (555.7 nm and 630 nm).

EO operations accounted for one-third of total mission observations on both Venus and skyglow, although data quality was limited by experiment optics and EO workload. Even so, the bulk of the EO acquired data can be used directly to augment PI results.

University of Colorado. The 12.5-cm spectrometer has yielded what appears to be good data, but a computer analysis will be required for a thorough assessment. Information to be derived includes, for example, the cloud cover of Venus (through observations of the Moon and Venus at the same wavelengths), and the Earth's atmospheric absorption in the near-UV region (through observations of the Moon at higher altitudes on the CV-990 and at the lower altitude of Mount Evans, Colorado). Unique spectral measurements were made in the near UV on several hot blue type stars in the constellation Scorpio. It appeared that observations could be made 25 nm farther into the ultraviolet at the CV-990 altitude (11,300 m, or 37,000 ft) than atop Mount Evans (4,350 m, or 14,250 ft).

EO observations again accounted for about one-third of the mission total for this experiment. Limitations on data quality due to optics in the telescope

system ahead of the spectrometer were common to this and the Alaska experiment. The Colorado optics, however, were greatly improved by the co-investigator after the simulation period, and yielded much higher quality data than it was possible for the EOs to obtain. Their contribution to the scientific results is thus of lesser value, but through no fault of their own.

University of New Mexico

Excellent data on OH atmospheric clouds were recorded. When correlated with time and aircraft position, the results will provide a more accurate determination of these clouds than had been previously possible. Preliminary indications are that some of the observed clouds are considerably higher than expected.

During the entire mission about 50 hr of data were obtained, including 2500 frames of 35-mm, 1-sec exposures and 45 hr of photometer data in several selected narrow bandwidths. Comparison of the photographic and photometric data will permit the determination of possible correlations between the type of OH structure observed with such factors as tropopause height, magnetic and solar activity indexes, local weather, and geographic features such as mountain ranges.

EO contributions to the scientific results were substantial. The experiment was well automated and reliable, allowing full-time operation with little attention. Thus, the EO generated nearly one-third of the total data obtained, with a quality fully equal to that recorded by the PI team.

Data acquisition was somewhat limited by (1) the large number of Venus runs during twilight, (2) the numerous ρ Ophiuchi runs during which the instruments viewed the highly structured region of the summer Milky Way in Scorpio and Sagittarius, and (3) the presence of the Moon on several of the flights. In spite of this and by utilizing both sides of the plane during nonsimulation flights, an average of more than 3.5 hr of data per flight were obtained from each of the three instruments for the 14 flights flown by this experiment. The equipment was removed on June 18, since the last two flights would have been either in twilight or with bright moonlight.

Experiment Problems and Operating Constraints

Research accomplishments have been described in the previous section. For Spacelab, however, there is perhaps greater interest in the problems encountered and solutions devised in the pursuit of research goals. It is hoped that through an identification of weaknesses that emerged under simulated Spacelab conditions, the same or analogous situations may be avoided in real life where the cost of failure, or of preventing failure, is of much larger consequence. In this discussion, problems are grouped by type or by functional system rather than by individual experiment. Specific problem categories, the nature of the problems, and the corrective actions taken, are listed in the appendix at the end of this report. In the following sections, problems in these categories are addressed.

Problems were encountered even before experiments were shipped to Ames; some were quickly resolved, while others had a profound and long-lived impact. With perhaps one exception, these and subsequent problems were adequately resolved and good experiment performance was achieved before the end of the mission. Some problems were aircraft related, with a loose-coupled but yet significant analogy to Spacelab. The majority, however, were more closely related.

As the laboratory stage of experiment development neared completion, preparations for integration became an important concern and interaction with the Mission Manager increased accordingly. Standard instrument racks were shipped to participants in October, and PIs were requested to submit detailed installation sketches and stress analyses of rack and custom-mounted equipment (details of Level IV integration planning) by early December. In most cases, these Level IV plans required one interaction to satisfy safety requirements; in two or three cases, several interactions were required. Even so, two experiment mounts were disqualified by airworthiness engineers at Ames, and several less significant but time-consuming errors had to be resolved. The three contributing factors were: lack of PI design experience with aircraft-type loading, the lack of on-site safety reviews by ASO due to budget constraints, and the inadequacy of some CV-990 Handbook information for Joint Mission participants.

Experiment Integration Period

Category I includes problems that occurred during the integration period. The nature of integration concerns (both in the home laboratory and at Ames) is indicated together with the corrective actions taken. Substantial ASO/Ames support was required to satisfy flight safety and experiment/vehicle interface demands, particularly for U.S. experiments. Unique schedule delays (one caused by shipping damage) had a serious impact potential this late in the program; two were resolved but one could not be. Three experiment interface mismatches were finally resolved, but one caused a significant data loss. Recognized deficiencies in design for EO operation of one or a group of experiments were partly made up by procedures lists and by on-the-job experience, but these "solutions" notably increased EO workload and the amount of learning necessary for effective experiment operation.

Inflight Experiment Operation

Category II problems are component malfunctions within experiments during the flight phases of the mission: checkout (CO), simulation (EO), or post-simulation (PI). With few exceptions, they were first observed in flight and directly affected data acquisition. Of a total of some 50 to 55 problems in this category, almost half had a serious impact on performance and fully one-fourth could have either forced shutdown of part or all of the experiment for the remainder of the mission, or severely degraded the scientific worth of the data. Fortunately, all but five of this latter group were identified and resolved (at least partially) during the checkout/integrated mission simulation period. The remaining five were a detector failure with no backup unit, a low-sensitivity optical system (enclosed package), an unsuitable control

(manual guidance) system, a marginally suitable optical window, and a low-sensitivity star tracker. Three occurred in a single experiment employing two new state-of-the-art instruments with relatively unknown characteristics.

The most frequent malfunctions occurred in data processors and signal electronics, with optical systems and recorder problems occurring at a lesser rate. These troubles were generally of a less serious nature and could be handled by the EOs. Detector packages and control systems had fewer but more serious problems. The former could not be repaired on location and required backup units to continue operation, while the latter were inherent design limitations that could not be properly resolved without major effort.

Experiment Support Systems (GFE)

Category III problems relate to GFE systems that supported experiment operations. Most were resolved prior to the simulation period by equipment and procedural changes. The notable exception was a vacuum system that had been inadequately defined in the original PI request for GFE support. Design capacity was revised upward by a factor of 6 prior to installation, and again doubled during the checkout period, but still was marginal for the large helium boiloff from the experiment. Surge limits on aircraft 60-Hz inverters prevented the use of yet a larger pump. By close attention to vacuum leaks the PI was able to achieve a pressure level suitable for experiment operation, but at some sacrifice in overall sensitivity.

Central Data Facility (GFE)

Problems in category IV are related to the central data facility on the aircraft (ADDAS). Historically, ADDAS has provided a valuable onboard capability to record primary research data and time-correlate them to flight parameters, as well as to process the input from several related experiments for near real-time comparisons. At the same time, the overall effectiveness of the system has been limited by its modest size and by the software workload imposed by closely spaced flight missions having different experiments and/or data-processing requirements. ASO management recognized these limitations, but anticipated that advance planning would enable PI requests to be implemented by ADDAS personnel for maximum effective utilization of the data system. To this end, PIs were asked to finalize their software requirements for the Joint Mission by mid-February, a date that was not uniformly honored.

As it turned out, the requests for ADDAS services exceeded the system capability in two respects - the rate of data acceptance and the amount of real-time processing. The resulting negotiations served to delay program implementation. Software preparation was further complicated by two requests for immediate postflight processing of ADDAS tapes in the Ames computer center to yield information for daily evaluation of results and planning for the subsequent flight. Even with additional manpower loading, these requests could not be fully implemented, in part because of delays in coordination of PI/ADDAS activities. Finally, on-line checkout of experiment/ADDAS integration was delayed by experiment problems late in the checkout period when time for program changes was very limited, with the result that inflight operation was subject to unnecessary faults and stops for much of the mission. For the Joint

Mission, then, it appears that both the level of coordination with PIs and the software development effort should have been greater and matured earlier.

EMI/EMC Effects

Protection from EMI, both radiated and conducted, was one of the design principles recommended as a guide to experiment development. ESA-sponsored PIs were required and NASA-sponsored PIs were requested to isolate, shield, and ground their equipment to minimize sources and pickup. Definitive measurements were carried out by ESTEC specialists during the mission; their results are given in reference 15.

Three experiments had serious EMI problems (category V) that resisted all efforts to correct them. Two sources were identified - the aircraft VHF radio (the CV-990 Handbook cautions the experimenter to avoid these frequencies) and the aircraft power distribution system - and radiated pickup was the primary concern for two of the three experiments. The third experiment was bothered by an ambient magnetic field that caused distortion of image-intensifier pictures; the offending source was not identified. In all three cases, some improvement was made by standard procedures such as shielding and cable rerouting. Two experiments acquired data of reasonable quality, but data quality for the third remained poor.

Schedules and Time Sharing

Category VI illustrates situations that required time sharing, at some compromise of individual goals, to achieve an integrated payload operation. At the level of overall flight planning, certain experiment priorities for the mission were established by the MPG, but the Mission Manager implemented the schedule. At the level of daily flight planning, the PIs and the Mission Scientist reached agreement (within mission guidelines and subject to Mission Manager approval) on specific targets and timing to complement previous results. Priorities for EO time in flight were decided by the PIs of coordinated experiments. And in flight, the EOs made real-time decisions to maximize experiment performance and data quality, including requests for assistance from an associate where time constraints were critical.

This multilevel distribution of time-sharing decisions proved effective during the simulation period. In the postmission period, flight profile decisions by the Mission Manager and operations decisions by the PIs followed normal ASO practice.

Vehicle Operations

This category (VII) is clearly more aircraft-specific than the others, but there is some analogy to Spacelab with regard to orientation relative to celestial light sources, latitude requirements, and time-of-day constraints. Such constraints resulted from the necessity to time-share flight profiles for the benefit of the total payload, with deference to those experiments having a priority designation. Even so, there were several opportunities for real-time deviation from the flight profile to accommodate special requests. These were decided by the Mission Manager, after consultation and approval of the flight crew. It is not unlikely that similar events can occur in Spacelab.

Two experiments had localized temperature problems. In both cases the PI depended on cabin air circulation for heat supply or dissipation, and no problems were anticipated since none had occurred in the laboratory. Although fixes were devised in flight for both experiments, this experience points to the need for heat management studies of Spacelab experiments.

Mission Management

In normal ASO operations, the Mission Manager bears full responsibility for mission planning and execution. Early recognition that both the simulation and the international aspects of the NASA/ESA mission would add greatly to mission complexity led to the assignment of an assistant mission manager shortly after the initial MPG meeting in January 1974. His primary responsibility was experiment integration and support systems, including the arrangement of equipment in the aircraft cabin. Even with an assistant, however, the myriad details of the Joint Mission were all but overwhelming for the Mission Manager.

The management areas in which most problems occurred were: (1) airworthiness engineering, (2) experiment development schedules, (3) coordination among PIs, and (4) ADDAS requirements and capabilities. Problems in the first area arose mainly because NASA lacked travel funds to send an Ames airworthiness representative to PI laboratories prior to the ERRs. Participation by an Ames representative at that stage would have avoided a number of time-consuming reworks of support bracketry and Level IV integration details. The normal requirements are stipulated in the CV-990 Experimenters' Handbook, but many details slip by PIs lacking flight experience. Further, as in every airborne mission, unique situations required investigation and decision. Although the majority of these were handled earlier, some were not recognized until the incoming inspection at Ames.

Problems in the second area arose for two reasons: the delay in selection of U.S. experiments and the lack of sufficient emphasis on ERR requirements. Delays in experiment completion had a significant impact on final integration and EO training schedules in the last weeks before the mission. In the third area of PI coordination, proxy operation by EOs involved human engineering, training, and time-sharing arrangements far greater than for normal ASO missions. At the time, the required level of management direction to achieve acceptable results was not known and, except for overall training and flight schedules, the details were left to the initiative of the individual PIs and EOs. This arrangement was not satisfactory, even with specific reminders from the Mission Manager; the EOs were not in a position to work across experiment lines, and PIs were primarily concerned with their own experiment. Greater management control clearly is needed to ensure timely and effective PI coordination among themselves and in terms of EO operating requirements.

The fourth management area in which problems occurred was the utilization of the central data system (ADDAS). This facility and any interfacing with the Ames computation center is supported by contract, both for software and operations. There was notable difficulty in communication between Ames personnel and the PIs until they met and could work on a one-to-one basis. Unique

REPRODUCIBILITY OF THE
ORIGINAL PAGE IS POOR

requirements could not be clearly defined by reference to the CV-990 Handbook, and misunderstandings meant delay. To compound the software problem, PI requirements changed as experiments neared completion. Thus, much work remained to be done at Ames involving program language, interface, hardware, signal input levels, and offline processing - all matters that should have been resolved much earlier.

Minor difficulties and some loss of experiment checkout time occurred when aircraft maintenance schedules conflicted with PI work plans. Compromises worked out by the Mission Manager or his assistant were not always acceptable to experimenters who were working a 16-hr day much of the time. Flight operations produced no management problems. The Mission Scientist was effective in dealing with planning activity that took place while the Mission Manager was flying or asleep.

ASSESS-SPACELAB SIMILARITIES

Although experiment installation and operation on the Joint ASSESS Mission cannot fully simulate a Spacelab payload and operation, there are many similarities between the two that provide a basis for identifying elements of ASSESS experience that are relevant to Spacelab experiment planning and operation. This section explores the parallels between simulated and planned Spacelab objectives, procedures, and operations. Relevant ASSESS experience and lessons applicable to Spacelab operations are discussed in the final section of the report.

General Mission Parameters

Spacelab:	Significant experiments to be conducted from Spacelab	ASSESS:	Authentic science conducted from aircraft

Real experiments in astronomy and atmospheric physics were conducted, taking advantage of the aircraft altitude to obtain data not possible from ground observations. As discussed earlier, satisfactory scientific results were achieved.

Spacelab:	Fixed countdown to liftoff	ASSESS:	Rigid schedule to takeoff

The block of time allotted for this mission was scheduled a year in advance as one commitment in a full-time research program for the CV-990. Time of month was fixed by phase of the Moon to minimize ambient light level for astronomical and skyglow measurements.

Daily takeoff times were controlled by the astronomical object first to be viewed - usually Venus. Precise positioning and heading of the aircraft were required to attain astronomical objects within the limited elevation angle capability of the telescopes.

Spacelab:	Orbiter and Spacelab operations to be separated	ASSESS:	Aircraft and experiment operations separated, yet both under the cognizance of the Mission Manager

All aircraft operations were handled by specialists - the ground crew and the flight crew. When necessary, the experimenters could interface with these specialists through the Mission Manager.

Spacelab:	Large weight and volume capability to be provided	ASSESS:	Ample weight and volume provided for Spacelab simulation

The passenger cabin of the CV-990 approximates in volume and dimensions the maximum space planned for Spacelab. However, the equipment on the Joint Mission was not arranged in a manner similar to Spacelab. The 20,000-lb payload capacity of the CV-990 aircraft is comparable to Spacelab and posed no limitation on the mission equipment.

Spacelab:	Relatively benign environment to permit use of laboratory-type equipment	ASSESS:	Mostly unmodified laboratory equipment used

In general, laboratory equipment was used without special modifications for the aircraft environment. In a few cases, flight safety rules required minor mechanical or electrical changes. Frequent use was made of stabilized optics to fix the viewing direction.

Spacelab:	Short development times planned for Spacelab	ASSESS:	Less than 1 year scheduled for ASSESS experiment development and flight

Several experiments were developed for flight from ground-based prototypes in a period of 7 months.

Services and Hardware

Spacelab:	Essential services (power, environment, etc.) and standard equipment fittings (racks, windows) to be provided	ASSESS:	Power and shirtsleeve atmosphere provided; standard racks and modified windows available

The basic power supply on the aircraft is 115-200 V, three-phase, 400 Hz from the engine generators. For experiment use, four 8-kVA 400-Hz converters are provided. To accommodate European experiments, 50-Hz power was provided for critical equipment such as TV systems, and 28-Vdc power was supplied as needed in small amounts. Only 60-Hz and 400-Hz power are regularly available at the experiment stations. This power is distributed through a control panel at the Mission Manager's station to 20 individual power boxes. Cables run from the power boxes to panels of receptacles on each equipment rack into which

laboratory equipment may be plugged using standard U.S. three-wire grounding plugs. Voltage and frequency are controlled to 2 percent or better, but the frequency is not sufficiently precise for timing applications. Current surge limits on the 60-Hz converters prohibit the use of electric motors larger than 1/2 hp (375 W). Temperature in the aircraft cabin was controlled by the flight crew to permit shirtsleeve operations.

Ames provides standard racks for mounting electronic and other equipment. The racks fasten to the seat rails and so may be placed in the best location. The racks take standard electronic panel-mounted equipment, but may also be used to support equipment such as telescopes and cameras.

The aircraft is provided with ports giving viewing angles of zenith, nadir, 65° above the horizontal, and 14° (the standard passenger windows). Selected passenger windows and any of the special ports may be fitted with special optical glass or other material such as IR transmitting plastic.

Data System

Spacelab:	Control and data management system (CDMS) to be provided	ASSESS:	Airborne digital data-acquisition system (ADDAS) provided

The CV-990 is equipped with an onboard data management system with a moderate computational capability (fig. 47). The system is used to record flight parameters from the aircraft's central air data and inertial navigation systems, data from experiments, and voice comments via typewriter input. The basic data are recorded in digital form on magnetic tape. Experiment data can be processed in real time, correlated timewise with flight parameters and comments, and printed out as real-time, hard-copy record. Selected data are also displayed on television monitors (10 sec update), and can be plotted or printed as hard-copy. Table 19 indicates the data system usage each experiment. Five experiments had self-contained data systems, three employed the aircraft ADDAS as the primary system, and all eight relied on the ADDAS record of flight parameters for data correlation.

Ground Operations

Spacelab:	Simplified ground operations planned	ASSESS:	Very simple acceptance and experiment integration procedures used

Experiment integration methods used for ASSESS were discussed previously in detail under MISSION GROUND OPERATIONS.

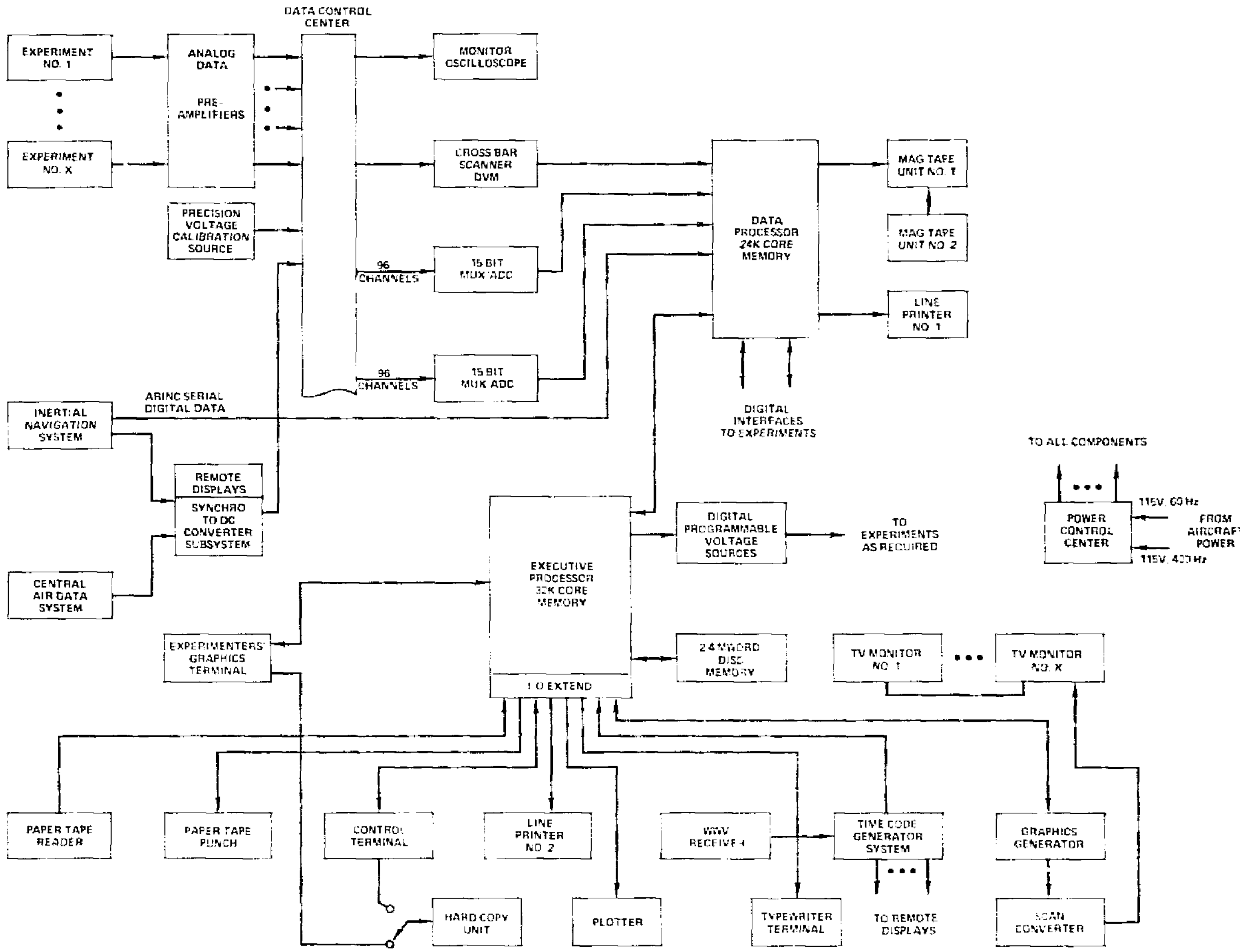


Figure 47.- Hardware configuration of Galileo II data system (ADDAS).

TABLE 19.- EXPERIMENTERS' DATA SYSTEMS

Institution	Experiment supplied	Airborne digital data acquisition system, CV-990 ADDAS		
		Use	Recording*	Real-time analysis
Queen Mary College	Redundancy	Primary	X	X
Jet Propulsion Laboratory	Redundancy	Primary	X	---
Ames Research Center	Redundancy	Primary	Analog type	---
		Redundancy	X	---
Meudon Observatory/ University of Groningen	Primary	Redundancy	Analog type	---
University of Alaska	Primary	Redundancy	X	---
University of Southampton	Primary - film & video tape	Flight data	X	---
University of New Mexico	Primary - film	Flight data	X	---
University of Colorado	Primary	Flight data	X	---

*A 14-channel magnetic tape recorder for analog signals is a separate, peripheral unit of the ADDAS system.

Spacelab: Common test equipment and tools to be available

ASSESS: Common test equipment and tools used

A standard group of tools was provided for use during the simulation week. The tool inventory was developed in consulation with the experimenters involved, and it included experiment-peculiar tools where necessary. A work station was installed in the aircraft for the simulation period (fig. 38). The common tool inventory was placed here along with the common test equipment and selected spare parts. In addition, a small 13-cm oscilloscope and a multimeter that are carried on the aircraft at all times were available to the EOs.

Payload Crew

Spacelab: Payload specialists and mission specialists to be confined to Orbiter/Spacelab for 7 days

ASSESS: Experiment operators and Mission Manager confined for 5-1/2 days

During the simulation period, the EOs and the Mission Manager were confined to the aircraft. A living/sleeping area was mounted on a lift van truck for positioning adjacent to the rear passenger door (fig. 48), and a cryogenic service area was located at the base of the forward passenger stairway (fig. 49).

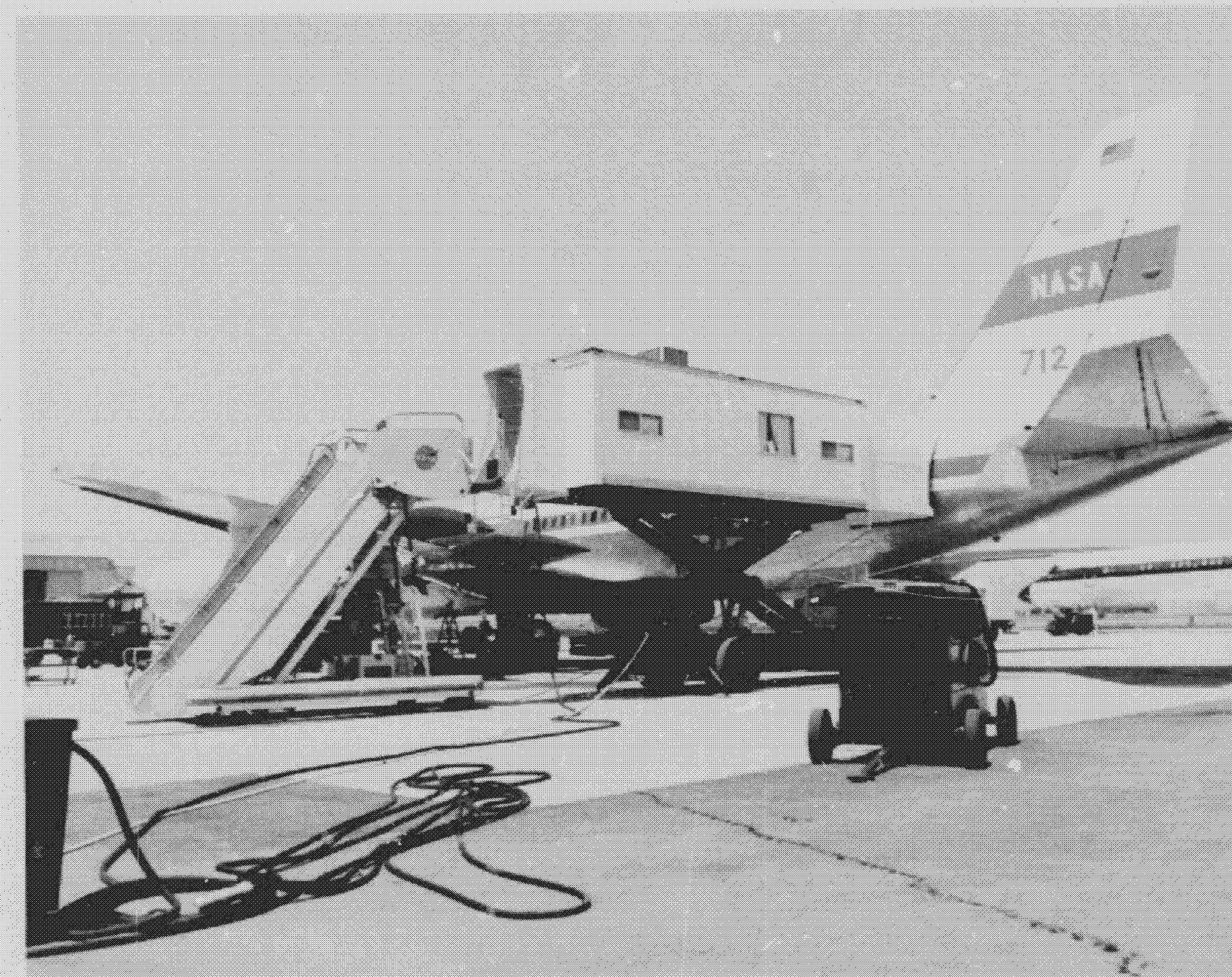


Figure 48.- Living quarters atop lift van at rear cabin door.

RODUCIBILITY OF THE
INAL PAGE IS POOR

Figure 49.- Cryogenic service area for simulation period.

REPRODUCIBILITY OF THE
ORIGINAL PAGE IS POOR

Spacelab.	Payload specialists to perform experiments; mission specialist to control resources	ASSESS:	Experiment operators performed experiments; Mission Manager controlled resources

In keeping with Spacelab guidelines, only three EOs were scheduled to operate at one time. The fourth was permitted to assist, briefly, during the start up of one group of experiments. It developed that mutual assistance between primary and secondary EOs on an experiment for periods of only a few minutes each was very beneficial for troubleshooting malfunctions.

The Mission Manager controlled power, data system, communication, and cryogenic resources. He coordinated overall payload operations with flight activities, and was the interface contact between payload and flight crews.

Flight Operations

Spacelab:	Communication to be provided between payload specialist and PIs on the ground through TV downlink and bidirectional voice link	ASSESS:	TV downlink and bidirectional voice link operational during periods the aircraft was on ground

During flight, no facilities were provided for communications between EOs in the aircraft and PIs on the ground. While on the ground during the simulation week, the aircraft was connected to the Mission Operations Center by two bidirectional voice links and a downlink video channel (with audio). A facsimile uplink was simulated by hand carrying small quantities of printed or graphic material when necessary.

Spacelab:	Experiment facilities to be used by more than one group of investigators	ASSESS:	Two PIs used common telescope by changing detectors at focal plane; two PIs used common telescope by placing beam reflecting mirror in optical path

The two primary examples of shared use of equipment on the ASSESS mission were the Ames/Groningen use of the Meudon telescope, and joint use of the Alaska telescope by the Alaska and Colorado experimenters. Ames and Groningen provided their own dewars and detectors to be attached to the telescope, as well as their own data-handling electronics. Physically, the two detector units were sufficiently different to require rebalancing of the telescope each time the units were changed. Because of the complexity of this operation and the time required to complete it, no attempt was made to change dewars in flight.

Shared telescope use by Alaska and Colorado experimenters was handled differently in that the sensing components were permanently mounted and a small, plane mirror was inserted into the optical beam to deflect it from one experiment to the other. However, similarities in observational objectives for the

two experiments led to scheduling difficulties, and the Colorado spectrometer was moved during the PI flights so that it time shared one of the JPL telescopes with a JPL instrument. Telescope use was now similar to the first type described: one sensing component was substituted for the other when a change in user was made; in this case, the conversion could be made in flight, since no balancing was required.

LESSONS LEARNED FOR SPACELAB

The Joint ASSESS Mission illustrated that a low-cost program with a low level of preparatory requirements, testing, and documentation can operate successfully under a simplified, focused, and directly interactive management approach. Appropriate and timely information on constraints and capabilities, as well as guidelines for hardware development, do enhance the chances for success. From the knowledge gained, it can be projected with reasonable certainty that an analogous approach will enable low-cost programs such as those envisaged for Spacelab to be successfully implemented.

This mission also showed that an aircraft can serve as an excellent platform for optimizing the methodology, design, and operations aspects of experiments conceived for Spacelab. This observation is particularly valid for experiments that are still in an embryonic stage, before large amounts of development time and money have been expended.

The lessons learned for Spacelab cover several specific areas. Some underline experience that is familiar to participants in the NASA Manned Space Program, but which may be new to ESA personnel preparing for Spacelab participation.

Management

Simplified management techniques can be effectively applied to experiment development, integration, and operations with a low level of imposed specifications and testing, resulting in relatively low cost, if the participants are competent and are strongly motivated.

The key to effective, low cost management of airborne or Spacelab missions is a close working relationship between the experimenter who is directly responsible for implementing his own research plans, and the Mission Manager who is responsible for coordination among participating experimenters, adherence to safety requirements, vehicle and support systems utilization, and overall planning of mission operations.

Experimenter centered responsibility for the development and performance of an experiment, as well as for the quality of research results, is not only a strong motivation for success, but also serves to minimize the amount of control and proof documentation required to implement a mission.

A small planning group with representation from each appropriate participating organization is effective in establishing policy and guidelines for mission implementation.

The Mission Planning Group (MPG) proved its value in setting the overall objectives of the mission and in developing guidelines for the implementation of the objectives. The group worked efficiently because it was small and composed of interested persons from the various organizations involved in management. The MPG did not include experimenters representatives. However, members of the MPG also sat in on meetings with the experimenters and so interacted with them in a reasonable manner. Details of the mission implementation were delegated by the MPG to the Mission Manager.

A Mission Manager with adequate authority can effectively execute the policies of the planning group and act as the single point of contact for the management of all mission integration activities. Such a manager must have the appropriate background to understand experiment objectives and instrumentation, and interexperiment and carrier interfaces. He should have a small and competent staff, working with him throughout all phases of the mission, to which he can delegate responsibility for details. To ensure effective coordination through all phases of the mission, the Mission Manager should not normally fly on Spacelab.

The responsibilities of the Mission Manager throughout the Joint Mission have been described. These management techniques, refined by ASO experience over a dozen years, have proven very effective in the management of airborne scientific research. The concept of a single point of contact makes it easy for the scientists involved to have their objectives and problems considered in a straightforward manner.

The manager for this mission had operated earlier missions with objectives in astronomy and atmospheric physics. This background and experience in these fields contributed significantly to the success of the mission. The scientists and operators must feel that they can talk on a professional level with the Mission Manager to ensure a satisfactory understanding of their objectives and problems.

The Mission Manager served quite effectively as Mission Specialist during the simulation period. This is normal ASO practice, which was established for three reasons: The staff is small, flight operations are self contained, and real-time decisions are vital to optimum payload operations. Management expertise thus is concentrated where it will be most valuable. But in the Joint Mission, the basic structure was different, with science planning by PIs and science operations by EOs as largely separate functions. For proper chronological coordination of the two functions, early data analysis and planning was done while the simulation crew was asleep. The major task of the Mission Scientist was to develop a plan for the next flight in consultation with the PIs, so that a detailed flight profile could be machine-computed and approved by the Mission Manager and aircraft operations personnel well before flight. An alternate solution was a separate Mission Specialist. The Mission

Manager's perspective of the total mission would perhaps have been better from the ground, with important onboard duties handled by a thoroughly trained Mission Specialist acting as interface between aircraft and the payload.

Spacelab operations similarly may be more effectively coordinated if the Mission Manager remains on the ground, again locating the expertise where it is most valuable. Certainly the Manager's staff will be substantially larger and more specialized, and interactions with vehicle support groups will be more complex. Furthermore, there will be communications with the Spacelab crew to facilitate on-ground science planning and, if necessary, real-time decisions to optimize payload operations. Thus, the Mission Specialist concept could be developed into a very significant role. In the event that a separate Mission Specialist is chosen, he should be a full-time member of the Mission Manager's staff through all phases of the mission. His associations and responsibilities will require background and experience similar in kind and second only to the Manager's. Thus, in practice, he should be an assistant Mission Manager.

> The application of ASO management practices to the Joint ASSESS Mission was generally successful, and these techniques can provide a valuable basis for the planning of Spacelab payloads and operations. As expected, however, the added complexity of Spacelab-type operations will require somewhat more rigid and formal arrangements than those normally associated with ASO payloads. In particular, a comprehensive implementation plan that details key activities is essential, to monitor experiment progress and promptly counteract delays.
>
> Reliance on the PI for development of his own experiment provides a high degree of motivation to ensure successful delivery and operation of the hardware. Free contact between the PI and other mission participants (via the Mission Manager) encourages the successful conclusion of these activities. Some limited formal review of experiment progress is needed, however.

Normal ASO practice for airborne experiments confers the entire responsibility for proper experiment operation on the PI. If the PI does not obtain satisfactory operation from his experiment, he is the loser, but no one else is directly involved. In Spacelab, however, the PI will probably not be operating his experiment, and its improper operation could detract from another experiment by requiring excessive time of the payload specialist. Thus, for Spacelab, some formal assurance of proper operation will be required.

The experiment readiness review (ERR) was used on the Joint Mission and the two previous Lear Jet simulation missions (refs. 8-10) as a means of checking on experiment progress. In principle, the experiment is in final configuration, fully tested, and proven operational by the ERR date, one month prior to shipment. The procedure is desirable, but needs further refinement to assure compliance. The ERR guideline was not viewed as a requirement on the Joint Mission and could not be enforced. For the ASSESS mission, experiment development and equipment changes continued right up until the first flights and interfered with the training of the EOs. To permit suitable training of Spacelab payload specialists, experiments must be in their final flight configuration at some reasonable time before launch.

Experiment/experiment interface areas require some management control to assure proper development of hardware, operator training, and time-share schedules.

A clear management responsibility exists when several experiments are grouped for a single operator or when equipment is shared by several investigators. The resulting interface areas require early definition to guide individual development efforts. Although this management function was specified in the Joint Mission, it was not implemented in sufficient depth to preclude significant problems. Whereas PI time-sharing relative to flight schedules and profiles was adequately managed, and overall EO training schedules were defined, the details of interexperiment planning were left to the PIs' initiative, with management in an advisory role. The result was not satisfactory. Communication among PIs was not adequate to resolve even some basic hardware interfaces, and planning and training for multiple-experiment operations was minimal.

The obvious lesson is that these interface areas should be bridged at a higher level of management where payload integration, rather than an individual experiment, is the primary concern. It is fair to say that the significance of this management role was perhaps not fully recognized at the outset, but became abundantly clear during final integration when actions were being taken by the Mission Manager to redress the most obvious deficiencies.

Relatively small amounts of control and interface documents and procedures suffice to ensure a successful low-cost mission, so long as the requirements are clearly specified. To be effective, this simplified documentation approach requires clear delegation of responsibilities to participants and quick and efficient communication among team members.

The small amount of documentation used on this mission proved sufficient and satisfactory except for two notable items. A number of experimenters pointed to what they considered deficiencies in the Experimenters' Handbook for the CV-990 aircraft. Their comments were constructive and revisions are being made. The other deficiency in documentation resulted from delays in experiment development schedules. The full attention of most PIs to their experiments well into the integration period precluded their preparation of training documents for the EOs at a reasonable time in advance of the final training period. Most of the checklists actually were prepared by the EOs and confirmed by the PIs. Management adherence to experiment development milestones would ensure that training documents were available when needed.

Experiment Equipment

Early in the development of the experiment equipment, the design of individual components must be guided by the fact that each experiment will be operated as an integral part of the total payload.

Little attempt could be made by PIs during the Joint Mission to coordinate the design of their several experiments for control by a single operator due to

funding limitations. As a result, the EOs were put to the additional trouble of operating experiments from physically separated control panels. The implication for Spacelab is that groups of experiments that will be operated by a single payload specialist must be coordinated early in the design process. Further, this requirement poses an additional burden on the mission management, as noted earlier.

Payload specialists can make significant contributions to experiment design, particularly in the area of equipment operation, if they become involved sufficiently early in the design process.

EOs believed that there were many human-engineering aspects of equipment design that they could have favorably influenced had they been involved in the experiment during the formative stages of hardware design. Even as late as the experiment-aircraft integration stage, the EOs were making suggestions for hardware and operation changes, many of which were implemented.

The probability of experiment success on a Spacelab mission should be demonstrated and confirmed well before payload integration begins. A reasonable level of risk should be accepted, but this cannot be defined if an experiment has not been proven operable in the flight configuration. In any case, the Mission Manager should have the option to deny flight approval.

One U.S. experiment in the Joint Mission payload consisted of new equipment that had not been sufficiently tested prior to installation because of schedule conflicts both internal and external to the PI's staff and organizational support. There was an obvious time constraint that prevented the timely development of the associated electronics, and the necessary familiarization of the PI and his team with the operational characteristics of the equipment. Inadequate review procedures failed to screen out this experiment and forced management to gamble on the outcome. Although much useful ASSESS information was gained, the scientific return was not satisfactory.

Another experiment consisted of a new instrument coupled to a telescope that (because of late delivery) had not been properly checked for optical alignment and stability. Experiment integration and testing were limited by time and funding. The complete electro-optic system was not assembled until the installation period at Ames. Although much was done to overcome the earlier deficiencies, the final result was reduced effectiveness of the experiment during the mission and a significant negative impact on an ass iated experiment that time-shared optical equipment.

Electromagnetic compatibility (EMC) engineering should be considered a basic requirement throughout the Spacelab payload design process.

The frequencies used by radio transmitters aboard the aircraft are listed in the Experimenters' Handbook so that these may be avoided. Two experiments nevertheless proved very susceptible to RF pickup when transmitters were operating. Such interference commonly enters experiments through high-impedance detector circuits. PIs and EOs lost considerable time in attempting to diagnose and alleviate these situations. Significant data degradation resulted from such

pickup. In another experiment, external magnetic fields caused some distortion of electron-beam images, but without serious loss of data.

In all three cases, the PI was unaware of the potential for trouble in his equipment, not because of unfamiliarity with EMC procedures but because he did not foresee a problem in the aircraft environment. This experience clearly suggests the need for laboratory tests during development to simulate the EMI conditions for Spacelab, especially when high-impedance circuits or electronic imaging devices are a necessary part of the experiment.

During the mission, EMI tests and measurements were made under the direction of ESTEC personnel. PI preparations for these tests undoubtedly reduced the influence of EMI on the experiments, while on-site measurements suggested some corrective actions. Unfortunately, the effort was not begun as an integral part of experiment design, nor was it available to U.S. experimenters before payload integration.

> Although the use of off-the-shelf equipment is encouraged, some minimal standard of performance should be established to avoid the low reliability that was noticed in some minor items, such as strip chart recorders.

Strip chart recorders, as a class of equipment, have consistently shown low reliability in airborne operations. However, experimenters find them convenient in examining trends in the data. Rather than discouraging their use altogether, it would be better to ensure that the operation of an experiment does not depend critically on a chart recorder. Alternately, much of the trouble could be avoided by using other recording methods, as for example, a heated stylus.

In a more sweeping indictment of recorders in general, one EO observed that each had a different procedure for loading, none of which could be done quickly and with complete assurance. He recommended that all Spacelab recorders be equipped with standard cassettes - whether for film, tape, or charts.

Another persistent cause of trouble was the loosening of electronic cards in their sockets by vibration during takeoff. The obvious remedy is to engineer better holddowns for such cards.

The implication for Spacelab is twofold: that minimum equipment performance standards should be adopted, and that all electronic equipment should be inspected by a specialist in (for example) airborne electronics who can suggest improvements in the equipment that will reduce the likelihood of problems.

> With no limitation imposed on power, volume, and weight, the demands of available equipment can be quite high. For example, on the ASSESS flights the values of these quantities were as follows:
>
> Volume: 10 m^3, total payload
>
> Weight: 1700 kg, total payload
>
> Power: 3 W/kg
>
> Although these values could be reduced by state-of-the-art advances, off-the-shelf equipment used on Spacelab may still require modification to satisfy payload constraints.

A significant difference between the CV-990 as a laboratory and Spacelab will be the basic electric power available. Adequate 60-Hz power was available on the aircraft. On Spacelab, the basic power supply will be 28 Vdc. The conversion of that basic power to 60-Hz power, only to have it re-rectified to dc for use within the equipment, will be wasteful of both power and total stored energy, and could become critical. Thus, it seems clear that as much equipment as possible should be modified from its off-the-shelf configuration to permit direct utilization of the 28-Vdc power.

> Minor (but time-consuming) activities, such as switching, should be automated to permit full concentration on the real experiment operation. All experiments should include displays that indicate proper operation.

Fixed sequential operations in experiments could be automated for the benefit of the payload specialist. Timers or other sequential types of switches can readily be tied to go-no-go indicators so that the operator may be made aware if some step fails to operate properly. Since the design of such switching circuits is a specialized branch of electrical technology, it would be reasonable for the management staff to aid experimenters with this portion of their equipment.

> Cryogenic support for experiments should be included in any general provisioning support system developed for Spacelab. On ASSESS, significant problems were encountered with experiment-provided cryogenic equipment.

Four experiments required cryogenic support in the form of 70 liters of LHe, 850 liters of LN_2, 6 kg ice, and 6 m^3 (standard) of helium gas during the 5-day simulation. 450 liters of the LN_2 was used to supply a continuous dry-gas purge to one experiment.

Four significant problems with experiments and one with GFE occurred during the entire mission. During the checkout flight period, two dewars were damaged by ice plugs and replaced with backup units, while the GFE LN_2 evaporator was flushed to remove trace-oil contamination. Malfunctioning equipment that caused the other two problems was repaired by EOs with verbal support from PIs, a leaking LHe evaporator that caused a partial ice blockage in one experiment, and a broken dewar insert that served as a helium-surge baffle in another.

Four minicomputers were provided as part of the experiment equipment, despite the availability of the ADDAS on the CV-990. The tendency of experimenters to provide their own minicomputers suggests that the need for CDMS for basic recording and computation may not be as great as originally anticipated. In addition, the Spacelab CDMS capabilities for interfacing with minicomputers should be investigated further. At the same time, however, the use of ADDAS emphasized the very real need for centralized handling of housekeeping data.

In general, experiments that included their own primary signal processing and recording faired better than those that relied on central recording. Self-reliant systems were system tested before installation in the aircraft and last-minute interfaces were avoided. Problems were avoided in noise, signal strength, and computer programming. On the other hand, there were a number of operational problems with dedicated minicomputers that resulted in some loss of data, and were not amenable to solution by the EOs except in consultation with PIs. It should be noted, however, that the local operations performed by these units under the guidance of the EOs would have been very difficult if not impossible to do on the ADDAS in a real-time frame.

This application of distributed data processing is only one example of a current trend in computer development in which the use of yet smaller units, microcomputers or microprocessors, can further reduce software complexity at the minicomputer level. Such a dual approach could greatly reduce the software requirements of the Spacelab CDMS, and at the same time allow the EO to respond to changing situations or unexpected events that influence the individual experiment.

Integration of experiments with the CV-990 data management system and its associated software presented problems on ASSESS. This area can be expected to be problematic with Spacelab as well, and will require special and timely attention.

Taken together, the great variety of experimenter demands on a centralized computation facility may exceed the capability of the system. Clearly, the design of software for such a facility will be very difficult and time consuming. Both limitations were experienced in the Joint Mission. An even more basic concern was expressed by several experimenters - that the use of a common computer might cause undesirable interexperiment interference. Optical coupling techniques for digital signals now becoming available should eliminate such problems.

Experiment/data system integration problems were partly due to the fact that the ADDAS was relatively new and not completely debugged in all possible operating modes. Also, the detailed requirements of the various experiments were not presented sufficiently far in advance, and kept changing. For these reasons, personnel assigned to computer operations had very limited time in which to make the necessary changes in software, and no opportunity to augment hardware in one or two areas where present capabilities are limited. On

...ODUCIBILITY OF THE
...NAL PAGE IS POOR

Spacelab, a very significant investment in time and adequately trained computer personnel will be necessary to make the most efficient use of the CDMS installation.

> Ground-based processing of scientific data contributes significantly to the successful proxy operation of experiments when large amounts of data have to be evaluated.

The CDMS on Spacelab will have a substantial computational capability, but for reasons iscussed should not be the primary processor. Large amounts of processing - calculation of Fourier transforms, for example - will require telemetering and ground computation. In the general case, therefore, the CDMS might better be used for data compacting to reduce transmission rates, with perhaps simplified processing of a few samples. This latter function was successfully performed in flight during the Joint Mission to guide the operator's control of his experiment in real time. With proxy operations, however, the best judge of data quality and research progress (the PI) is on the ground. Without question, the computation and availability of data to the PI at the ground computer center will enhance the feedback of relevant information and instructions to the operator in Spacelab.

> During tracking and pointing operations, a dedicated keyboard and display is required. It is questionable whether time sharing of a single keyboard and display by several users can provide satisfactory results.

During the Joint Mission, three experiments each utilized a keyboard and display essentially full time. It was obvious that the same equipment was not available for time sharing by another experiment. For Spacelab, utilization of such equipment must be carefully timelined in advance, and in consultation with the PIs and payload specialists, to determine if any time sharing of such equipment is possible.

> A downlink TV capability will be important for occasional repair tasks, but probably will not be required frequently for normal Spacelab experiment operation.

The downlink TV was sparingly used during the Joint Mission during periods when the aircraft was on the ground. EOs and PIs agreed that it was a valuable adjunct to repair work. (See also references 9 and 10 on the fourth Lear Jet ASSESS mission.) However, none could see that its use would materially aid normal experiment operation in real time; rather, it could be a significant distraction in a very busy EO work schedule.

> Nominal experiment operations should not require real-time communications with ground-based PIs. Principal investigator/payload specialist conferences, however, should be scheduled on a regular basis.

The EOs found that they could operate experiments satisfactorily without any real-time communication with the PIs. In fact, most EOs felt that outside communications of any kind during experiment operations would be a handicap to

operation of the experiments. However, the immediate postflight debriefings and subsequent communications with the PIs on a scheduled basis to fit the workload proved beneficial to both the EOs and the PIs. Spacelab communication between payload specialists and PIs should be scheduled during nonoperating periods.

Experiment setup times and procedures can represent a major part of experiment operation and must be considered in developing the mission timelines.

Although notable success was achieved in reducing manpower loading, none of the experiments on the Joint Mission had been refined to the point of being easy for an EO to use. Each experiment was provided with a large number of controls and adjustments. Thus, experiment operation, particularly startup operations, required an inordinate amount of attention from the EOs. Mission timelines were affected by the inability of the EO to operate all the necessary controls on several experiments simultaneously. All recommended an increased amount of automation for basic control operations.

Payload specialists should normally not be responsible for subsystem operation and maintenance, but should concentrate fully on payload operation.

Experience on the Joint Mission showed that EOs had little or no time during experiment operation to attend to subsystems. Furthermore, any time spent training in these tasks would have detracted from EO preparations for their assigned research duties.

Vehicle subsystems that support experiment operation - for example, CDMS or cryogenics resources - are not the province of the payload specialist, and any effort in this direction will detract from his primary assignment. The operation and maintenance of these systems should be handled by the Mission Specialist who has been trained in their use, and his backup should be one of the orbiter crew. A high level of automation will be required of these subsystems to minimize routine tasks and free the Mission Specialist for creative interaction and direct support (as required) of the research team.

EO Selection and Training

Selection and training of payload specialists for Spacelab missions will be critical elements in the overall success of the mission. From the unique EO/PI relationship evaluated during the Joint ASSESS Mission, it is apparent that the Spacelab payload crew should comprise specialists who can interpret the data and can develop an intuitive feeling for the measurements. They should understand the experiment and its objectives and should have sufficiently detailed knowledge of electromechanical aspects of experiment hardware to permit troubleshooting and correction as warranted.

The EOs on the Joint Mission were all trained scientists in fields at least closely related to those represented by the experiments they operated. The EOs felt that their scientific knowledge of the experiments eliminated the need for much background indoctrination.

The EOs also felt that they needed to be trained experimenters to develop a feel for the experiments and their indicated results, and to minimize the training required for the mission. They also noted that EOs must be quite knowledgeable about the electromechanical aspects of the experiment - that is, they should not only know how to operate it but should understand its operation thoroughly. Only then could they be expected to perform any unusual maintenance and troubleshooting. All agreed that there is a bit of mystique in the ability to handle electronic equipment, particularly to service it efficiently. All of the EOs were capable of operating electronic equipment to this requirement, and one had outstanding skill in troubleshooting.

Payload specialist participation in experiment development, integration, and payload checkout phases is highly desirable. Therefore, payload specialists should be selected and start their training early enough to enable them to participate during these phases.

The development of a scientific experiment for proxy operation should involve both the experimenter and the operator in all its phase for best results. In the Joint Mission, EO input was delayed in some cases until final assembly or even later. As a result, the PI almost always and quite naturally gave first priority to science-related tasks, and paid little attention to layout of controls, displays, and procedures for efficient operation. T was particularly true where several experiments were to be combined into one operational group. To avoid this situation in Spacelab, the EOs strongly recommended that payload specialists become involved sufficiently early in the experiment design to provide meaningful input to the development and coordination of control hardware and operations plans.

Similarly, the EOs found that the payload integration and checkout phases were a necessary part of their training in the operation of the experiment. They recommended that Spacelab payload specialists have the same opportunity to participate in payload checkout as a part of their training.

The EOs also made numerous suggestions regarding the design and operation of the experiments during the final integration and operational phases of the mission. As late as they were, many of these suggestions were still adopted by the PIs. The EOs felt they could have made even more improvements had they been involved at an earlier stage of the experiment development.

Payload specialist training should be well planned and organized as an integral part of the total mission, and should include substantial training at payload level for which adequate equipment is required to fully exercise the man-machine interface.

Adequate time was scheduled for EO training during the Joint ASSESS Mission. Unfortunately, the time was not used as effectively as planned, largely because experiments were not completed in time for integrated training. EOs made visits to experimenters' home locations, but seldom did they have an opportunity to operate anything like a complete experiment. Thus, the final stages of training after payload integration assumed more importance than originally planned. The integrated mission simulation period (as short as it was) was perhaps the most valuable of all training experiences, since for the first time the operator was exposed to near-real constraints. In fact, a strong recommendation was made by the EOs that more time be allotted to this full-simulation training, both in future ASSESS missions and in Spacelab.

Limited presimulation flights of the ASSESS EOs and payload were an extremely important factor in their training, adjustment to environment, and overcoming latent snags. This experience suggests that Spacelab payload specialists will benefit from aircraft flights with their equipment or some equivalent form of integrated mission simulation.

Early flights proved unsettling to EOs who had not flown with experiments before or had had little flight experience. Environmental factors such as darkness, noise, head sets, close quarters, and aircraft motion were distracting. On later flights, these EOs became seasoned veterans who were able to perform well despite such distractions.

The development of a payload specialist/PI team relationship is essential to successful experiment proxy operation.

The EOs and PIs on the Joint ASSESS Mission developed excellent working relationships based upon mutual understanding and trust. Hardly less important were the team relationships developed among the Mission Manager, the EOs, and the PIs. These working relationships developed naturally out of months of working together toward a common goal. Continuity of relationships will be similarly beneficial in Spacelab.

Mission simulations should include practice in payload specialist/PI communication under realistic conditions.

Effective verbal communication was an acquired skill requiring a definite learning period. Data records alone did not provide sufficient information, and the PIs expected to use EO commentary during experiment operation to aid assessment of research progress and equipment malfunctions. Thus, EO comments were typed into the ADDAS record in real time during flight, and hard copies were made available to the PIs at the flight debriefing meeting. However, this mode of communication was never effectively developed; EOs were not trained to utilize the intercom for this purpose and so did not find time in their busy schedule to make an adequate record.

When problems were being worked out on the ground between simulation flights, it was several days before EOs could communicate accurately and effectively with PIs - a further demonstration of the need to develop skill in verbal documentation of payload specialist activities in Spacelab.

A marked improvement in EO performance was noted as the simulation period advanced, implying that training and extended flight duration are important aspects of Spacelab operation. In addition, at least one payload crewman should be well trained in maintaining facility equipment.

Following the simulation period, the EOs indicated that they were still improving their performance, especially on their secondary experiments. All agreed that a longer period for a Spacelab mission would be desirable to assure peak performance from payload specialists. One EO even remarked that the currently planned 7-day mission for Spacelab would be a "disaster."

As noted previously, payload specialists should not have operatio... or maintenance responsibility for basic facility equipment. However, the EOs felt that in case of trouble with such equipment, one operator should be knowledgeable about facility equipment and should be able to carry out simple trouble-shooting and repair on an emergency basis, as backup to the Mission Specialist. Under such circumstances, he could work in communication with cognizant ground persons.

CONSIDERATIONS FOR THE FUTURE

The planning group for any future Spacelab simulation mission should consider the results of this first Joint Mission in developing mission guidelines. The new guidelines should probably include somewhat more formal management techniques and a longer period of integrated payload training for EOs. Considerable thought should be given to the simplification of experiment operation for the benefit of the EOs. The planning group might also consider other means of improving the realism of the simulation within the limits permitted by the aircraft to be used.

It should be noted that guidelines for this mission were selected before the capabilities of Spacelab and its resources were finalized. Consequently, some of the basic simulation objectives and guidelines may have to be modified to reflect current Spacelab thinking, in planning for any future ASSESS missions.

REFERENCES

1. Mulholland, D. R.; and Neel, C. B.: Airborne-Science Techniques Aid Shuttle Planning. Aeronautics and Astronautics, May 1973, pp. 24-32.

2. Mulholland, D. R.: A Cost-Effective Approach for Flight Experiments: Application of Airborne Science Aircraft Experience to the Shuttle Sortie Lab. Presented at the 24th International Astronautical Congress, Baku, USSR, Oct. 7-13, 1973. Published in Raumfahrtforschung, Band 18, Heft 4, July/Aug. 1974.

3. Mulholland, D. R.; Reller, J. O., Jr.; Neel, C. B.; and Haughney, L. C.: Study of Airborne Science Experiment Management Concepts for Application to Space Shuttle, Volume 1, Executive Summary. NASA TM X-62,288, July 1973.

4. Mulholland, D. R.; Reller, J. O., Jr.; Neel, C. B.; and Haughney, L. C.: Study of Airborne Science Experiment Management Concepts for Application to Space Shuttle, Volume II. NASA TM X-62,287, July 1973.

5. Mulholland, D. R.; Reller, J. O., Jr.; Neel, C. B.; and Haughney, L. C.: Study of Airborne Experiment Management Concepts for Application to Space Shuttle, Volume III, Appendixes. NASA TM X-62,289, Aug. 1973.

6. Mulholland, D. R.; Reller, J. O., Jr.; Neel, C. B.; and Mason, R. H.: Shuttle Sortie Simulation Using a Lear Jet Aircraft, Mission No. 1. NASA TM X-62,283, Dec. 1972.

7. Reller, J. O., Jr.; Neel, C. B.; Mason, R. H.; and Pappas, C. C.: Shuttle Spacelab Simulation Using a Lear Jet Aircraft, Mission No. 2. NASA TM X-62,352, Jan. 1974.

8. Reller, J. O., Jr.; Neel, C. B.; and Mason, R. H.: Shuttle Spacelab Simulation Using a Lear Jet Aircraft, Mission No. 3. NASA TM X-62,410, Nov. 1974.

9. Reller, J. O., Jr.; Mason, R. H.; and Neel, C. B.: Preliminary Report on Lear Jet Shuttle/Spacelab Simulation, Mission No. 4. NASA TM X-62,408, Dec. 1974.

10. Reller, J. O., Jr.; Neel, C. B.; and Mason, R. H.: Spacelab Simulation Using a Lear Jet Aircraft, Mission No. 4. NASA TM X-62,474, Oct. 1975.

11. Neel, C. B.; Weaver, L. B.; and Pappas, C. C.: Preliminary Report on CV-990 Shuttle Simulation Mission No. 1. NASA TM X-62,358, April 1974.

12. Anon.: NASA/ESA CV-990 Spacelab Simulation, Executive Summary. NASA TM X-62,457 and ESA-SL-75-1, July 1975.

13. Ames Research Center: NASA CV-990 Airborne Laboratory Experimenters' Handbook. NASA, Ames Research Center, Moffett Field, CA, April 1973.

14. Anon.: NASA/ESRO Spacelab Accommodation Handbook, Preliminary Issue. ESTEC Ref. SLP/2104, Oct. 1974.

15. Bachmann, H.; and Steinz, J. A.: EMI Test Report, ASSESS Mission 1975. ESA/ESTEC Test and Engineering Division, Issue date 76-01-09, Ref. TTA/76/2255.

ABBREVIATIONS AND ACRONYMS

AAO	Airworthiness Assurance Office
ADDAS	Airborne Digital Data Acquisition System (CV-990)
AFSRB	Airworthiness and Flight Safety Review Board
ARC	Ames Research Center (NASA)
ASO	Airborne Science Office
ASSESS	Airborne Science/Spacelab Experiments System Simulation
CDMS	Control and Data Management System (Spacelab)
COL	Colorado (University of)
CRT	cathode ray tube
DVM	digital voltmeter
EMC	electromagnetic compatibility
EMI	electromagnetic interference
EO	experiment operator
ERR	experiment readiness review
ESA	European Space Agency (formerly ESRO - European Space Research Organization)
ESTEC	European Space Technology Center (part of ESA)
FOV	field of view
DFRC	Dryden Flight Research Center (NASA)
FSB	flight safety briefing
GFE	government-furnished equipment
GSE	ground support equipment
INS	inertial navigation system
IR	infared
IT	image-intensifier tube

JPL	Jet Propulsion Laboratory (NASA)
JSC	Johnson Space Center (NASA)
MOC	Mission Operations Center
MOC	Mission Operations Center
MOP	Mission Operating Plan
MPG	Mission Planning Group
MRR	mission readiness review
MSFC	Marshall Space Flight Center (NASA)
NASA	National Aeronautics and Space Administration
NM	New Mexico (University of)
PCB	printed circuit board (electronics)
PI	principal investigator
PMT	photomultiplier tube
QMC	Queen Mary College, University of London
RF	radio frequency
RFI	radio frequency interference
SH	Southampton (University of)
TAOF	tunable acousto-optical filter
UV	ultraviolet
VHF	very high frequency

ROSTER OF PARTICIPANTS IN NASA/ESA CV-990 ASSESS MISSION

This roster gives the names of those directly involved with the mission and their organizational affiliations. There are no doubt others who made substantial contributions to the success of this Joint Mission, whose names have been overlooked. In particular, many participated in development of the experiments but were not at Ames for the operations period.

Without the timely support of many other segments of the Ames organization the Joint Mission could not have been kept on schedule. Particular thanks are due those in the Procurement Division, the Model and Instrument Machining Branch, the Aircraft Services Branch, the Computer Operations Branch, the Electrical Services Section, the Storage and Shipping Section, and the Security Branch who responded to our requests, sometimes on short notice and at odd hours, with their best efforts.

Mission Planning Group

G. D'Onofrio, NASA Headquarters
R. Lovelett, NASA Headquarters
M. Dubin, NASA Headquarters
J. de Waard, ESA Headquarters
D. Mulholland, NASA/ARC
J. Allen/R. Parker, NASA/JSC
L. Weaver, NASA/MSFC

Mission Management

R. Lovelett - NASA/ESA Panel, NASA Headquarters
J. de Waard - NASA/ESA Panel, ESA Headquarters
L. Haughney - Mission Manager, NASA/ARC/ASO
J. Reller - Asst. Mission Manager, NASA/ARC/ASO
R. Cameron - Mission Scientist, NASA/ARC/ASO
E. Miller - Asst. Mission Scientist, NASA/MSFC
J. de Waard - Mission Coordinator, ESA Headquarters
J. Graf - Deputy Mission Coordinator, ESA/ESTEC
C. Neel - ASSESS Program Manager, NASA/ARC/ASO
C. Pappas - ASSESS Facilities Manager, NASA/ARC/ASO

Headquarters Mission Support

W. Armstrong - NASA Headquarters
U. Sakss - NASA Headquarters
D. Shapland - Spacelab Program Office, ESA Headquarters

REPRODUCIBILITY OF THE
ORIGINAL PAGE IS POOR

Mission Support - NASA/ARC

Operations Planning

D. Mulholland - Chief, Airborne Science Office (ASO)
J. Kroupa - Flight Planner/Navigator, ASO
R. Morrison - Flight Planner/Navigator, ASO
D. Nelson - Flight Planner/Navigator, Northrop Services, Inc.
C. Muehl - CV-990 Facilities Manager, ASO
J. McClenahan - Data Systems Specialist, ASO

Experiment Integration

H. Turner - Chief, Airworthiness Assurance Office (AAO)
R. Davidson - Safety of structural and mechanical systems, AAO
P. Dexter - Safety of electrical systems, Electro-Systems Engineering Branch
D. Buell - Research Scientist, Aeronautical Structures Branch
A. Campbell, E. Menefee, S. Kurasaki - Structural design and stress analysis, Research Equipment Engineering Branch
J. Anaya - Inspector, Aircraft Inspection Branch
E. Vernon - Chief, Metals Fabrication Branch (MFB)
R. Soulages - Asst. Chief, MFB
J. Eddy - Project Leader, MFB
D. Christensen, J. Collins, D. Costa, M. Cucuza, L. deWitt, F. Johnson, D. LaForge, G. O'Connell, W. O'Dolly, D. Vandendriesche, W. Vanderbeek, J. Weller - Technical support, MFB
D. Gowan - Optical window management, W. V. Sterling, Inc.
A. Morningstar - Heliostat technician, Aircraft Services Branch
C. Schultz, C. Hancock, R. Danna - Aircraft electronics technicians, Northrop Services, Inc.
G. Olczak - Photographer, Photographic Technology Branch

ADDAS Operations

D. Wilson - Group Leader, Informatics, Inc.
J. Peck, S. Nelson - Programmers and inflight operators, Informatics, Inc.
M. Tavolarella - Programmer; ground data processing, Informatics, Inc.
E. Hodson - Ground data processing, Informatics, Inc.
J. Caballes, E. Carellas - Inflight data typists, Northrop Services, Inc.

Aircraft Flight Crew

F. Drinkwater - Command pilot, Aircraft Operations Division
R. Innis - Pilot and Chief, Flight Operations Branch (FOB)
G. Stinnett - Pilot, FOB
G. Hardy - Pilot, FOB
C. Mattraw - Pilot and flight engineer, FOB
S. Colpitts - Pilot and flight engineer, FOB
F. Fulton - Pilot, NASA/DFRC
E. Mitz - Flight engineer, Northrop Services, Inc.
R. Gallant - Communications and Personnel Safety Specialist, FOB

Aircraft Support and Maintenance

F. Schroeder - Manager, Northrop Services, Inc. (NSI)
R. Legg - Asst. Manager, NSI
V. Nespolo - Mechanical systems
C. Berg - Avionics systems — Engineering support, NSI
F. Wilson - Electrical systems
J. Watson - Chief, Maintenance Crew, NSI
P. Wolfe - Aircraft Inspector, NSI
L. Collins
J. Dyson
G. Gibson — Technical support, NSI
A. Hill
M. Lakowski
D. McKinnon

Operations Support

R. Maines - Chief, Security Branch
R. Miller - Communications Specialist, Electrical Services Section
H. Schacht - Laboratory Manager, ASO
A. Teshima - Admin. Assistant, ASO
D. Johnson - Secretary, ASO
L. Miser - Secretary, ASO
C. Keith - Ames Cafeteria, Stewart-Hill Co.

Experimenter Teams[1]

Meudon Observatory

Principal Investigator
Deputy PI
Co-investigator
Engineer, CNRS Meudon
Electronics Engineer, Meudon Observatory

[1]Names have been omitted to conform with provisions of the U.S. Privacy Act of 1974.

Meudon Observatory - Concluded

Engineer, Meudon Observatory
Electronics Technician, Meudon Observatory
Electronics Technician, CNRS Meudon
Data Systems Engineer, LPSP Verrières
Software Engineer, CNES Toulouse

University of Groningen

Associate Investigator
Associate Investigator
Electronics Technician

Queen Mary College

Principal Investigator
Co-investigator
Associate Investigator
Engineer

University of Southampton

Principal Investigator
Co-investigators (2)

Ames Research Center

Principal Investigator
Co-investigator

Jet Propulsion Laboratory

Principal Investigator
Systems Engineer
Electronics Engineers (2)

University of Alaska

Co-investigators (2)
Engineer
Systems Analyst

University of Colorado

Co-investigator

University of New Mexico

Principal Investigator
Co-investigator

Related Research Investigations

ESTEC EMI Study

H. van Looy - ESA/ESTEC
H. Bachman - ESA/ESTEC
J. Purchase - ESA/ESTEC
S. Shankle
C. Doggett
R. Amrine
Engineering support, Aeronutronic-Ford, Western Development Laboratories

NOAA Atmospheric Water Vapor Study

P. Kuhn, NOAA

Official Observers

J. Horner, NASA/MSFC
R. McBrayer, NASA/MSFC
J. Burger, ESA/ESTEC
N. Kiehne, GFW - Germany

ASSESS Mission Observer Team - Northrop Services, Inc.

B. Vernier - Manager
G. Androes - Senior observer
D. Annesley - Observer
N. Donnelly - Observer
J. Reeves - Senior observer
C. Schuppe - Observer
E. Carrellas - Secretary

APPENDIX

DESIGN AND OPERATIONS LIMITS TO EXPERIMENT PERFORMANCE

The appendix lists various constraints and malfunctions observed to limit the performance of experiments during the Joint Mission. For completeness, the list covers the entire period from the start of experiment integration until the end of the PI flight phase. Events that occurred during the simulation period and required EO response are identified in the tables.

Limiting situations are cast as problems in one of several categories: Category I covers the experiment integration process; category II the operating malfunctions in experiments during flight; category III the problems of facility systems that provided experiment support; category IV the limitations of the central data system; category V the EMI situation; category VI the schedule and time-share constraints; and category VII the vehicle operations constraints. In each case, a short description of the problem impact and its resolution are given. A general discussion of performance limits is presented in the MISSION RESULTS section of the main text under the heading Experiment Problems and Operating Constraints.

CATEGORY I - PROBLEMS DURING INTEGRATION PERIOD*

Area of Concern	Problem Definition	Impact	Resolution
Standard rack loading (flight safety)	Over moment limits at wall rail	None; advance notice given	Add load plate supplied by Ames
	Use of flammable or toxic materials	None; corrected before shipping	ASO recommends design mods.
	CG too high or too far outbd	None; corrected before shipping	Rearrange components per ASO suggestions
	Poor workmanship	10-man hours work	Unload, clean up, install at Ames
Special instrument supports in cabin (flight safety)	No home laboratory design personnel (2)	Time to fit and modify delays assembly 1-3 days	Design and build all supports at Ames
	Need design of interface with aircraft (2)	Few hours delay at assembly, advance notice given	Design and build interface supports at Ames
	PI structures disqualified at Ames (2)	Delay assembly 3 days	Modify design and rebuild at Ames
	Mechanical mismatch between experiment and Ames-built support (4)	Slows integration of experiments	Resolved by Ames shop personnel
External fairings/penetrations (interfaces)	Telescope fence effect on vehicle aerodynamics	Small loss of observing time; increased noise level in cabin	Ames flight tests measure control and buffet effects; flight velocity limited; flight plans adapted by Mission Manager
	Vacuum system exhaust ports needed to assure maximum performance	None; advance preparations	Approved port location utilized
	Plastic IR window required	None; advance preparations	Design, build, and test at Ames
	Guide optics vignetted by window frame	Some data loss on checkout flights; modified after flight 3	Redesign and build support at Ames

CATEGORY I - PROBLEMS DURING INTEGRATION PERIOD - Continued

Area of Concern	Problem Definition	Impact	Resolution
Electrical requirements (flight safety)	Starting arcs on motors (3)	None	Replace starting switch (2) at Ames Evaluate and approve (1) at Ames
	Motor current limiting devices to protect 60 Hz inverters (2)	Delay assembly 1 day and interference with checkout (1)	Increase rating by steps (1) at Ames
Experiment schedule delays	Late delivery of new instrument cancels test program	Significant loss of data during mission	Not resolved
	Late delivery of optics delays assembly of experiment	Optical alignment delays presimulation checkout	Checkout completed before simulation but early performance marginal
Experiment interfaces (at Ames)	Telescope image size not matched to instrument	Data quality significantly reduced for one experiment	Reconfigure optics after simulation period with ASO assistance
	Dewar mounting interference and CG offset	Delay installation and checkout several days	Modify dewar to fit existing flange; devise balance technique
	Final alignment incomplete	Delay integration schedule	Completed during checkout flights
Shipping damage (schedule delay)	TV camera inoperative	Delay integration and checkout several days	Repairs attempted but not satisfactory; fly in replacement
	PC boards malfunction	None	Repaired before flight
	Computer damaged	None	Manufacturer's representative repaired before flight
	Leads broken	None	Repaired by experimenter
	IC chips loosened	None	Located and reseated

CATEGORY I - PROBLEMS DURING INTEGRATION PERIOD - Concluded

Area of Concern	Problem Definition	Impact	Resolution
Human engineering	Experiment controls not centralized (3)	Control more difficult, occasional loss of data	None
	Controls of experiment groups not coordinated (2)	EO workload increased	Detailed procedures lists, necessary but time consuming
	Inadequate panel lighting	Slows operation by EOs	PI builds safety lights for one experiment. One EO uses a headlamp; others use flashlights but these not satisfactory for jobs requiring two hands
	High noise level in cabin from telescope port fence	Distracted EO's attention	Became acclimated
	Cryogenics handling not standardized	Refill problems for EOs	Learn by experience
Experiment assembly	Optical components misaligned	Some delay of final integration	Modify before flight
	Use of nonapproved hardware (2)	Slows integration of experiments	Replace after installed in aircraft

*Problems related to Central Data System in Category IV

( )Number of experiments with problem

CATEGORY II - INFLIGHT MALFUNCTIONS OF EXPERIMENTS*

Component or System	Problem Definition	Impact	Resolution
Automated film cameras	Drive train failed (CO)	Manual operation required+	Borrow camera from Ames, redesign mount to fit
	Time lapse unit failed (CO)	Data lost during checkout+	PI builds replacement unit
	Timer fuse failed (CO)	Data lost during checkout+	Use voltage control transformer
	Drive clutch slips (CO)	Checkout data lost	Convert to positive drive
	Drive motion stops (CO)	Lost data on one flight+	Repaired on ground
Detector packages	Cryogenic dewars twice overpressured (CO)	Lost data on two checkout flights+	Use backup unit first, then fly in a replacement
	Optical filter mechanism failed (CO)	Some data loss one flight	Repair after flight
	PMT failed (PI)	Data lost two PI flights+	Hand carried to manufacturers for repair (no backup)
	High background count on PMT (ALL)	Poor signal discrimination+	Replace with alternate unit when not in use
	Vibration sensitivity in two experiments (CO)	Detector microphonics degrade data	Vibration reduced by stiffening dewar mount; second not resolved
Optical systems	Spectrometer grating sticks twice (EO)	Some data loss on two flights	Take apart, inspect and clean after simulation flights
	Telescope guide optics not aligned (CO,EO)	Frequent loss of observation time	Reposition in flight, but never completely resolved
	Optical window absorption (EO,PI)	Reduce and distort IR signal on 11 flights+	Eliminate with effective aerodynamic spoiler
	Low sensitivity of tunable filter (ALL)	Serious loss of data, all flights+	Not identified or resolved
	Sensitivity to vibration (ALL)		
	a. during takeoff	Shift of components	Easily adjusted
	b. normal flight	Optical alignment uncertain	Adjusted with difficulty

CATEGORY II - INFLIGHT MALFUNCTIONS OF EXPERIMENTS - Continued

Component or System	Problem Definition	Impact	Resolution
Signal electronics	DVM erratic (EO)	None; work around	Repair on ground
	High noise level output (EO)	Degrade data quality	Troubleshoot; not isolated in flight
	Sensitivity to vibration (ALL)	Minor; time only	Reseat electronic card
	Fuses fail in power supply (EO)	None; at end of flight	Replace on ground
	Low signal level (EO)	Degrade data quality	Troubleshoot; not isolated in flight
	Erratic lock-in amplifiers in two experiments (CO,PI)	Degrade data, one flight each	Repair one inflight, second on ground
	No oscilloscope display (EO)	Hampers data acquisition	After flight repairs
	Low sensitivity (EO)	Reduced data quality	Problem not identified in flight
	Fuse fails in CRT display (EO)	Could not monitor data output	Identify and replace after flight
	Thermocouple amplifiers fail (PI)	Loss of IR window temperature, two flights	Repair after flight
Recorders	Strip-chart recorder fouls (EO)	Minor data loss	Adjust in flight
	Strip-chart recorder fails twice (EO,CO)	Operations delayed; some data loss	Replace units; once in flight (EO), once on ground (CO)
	Tape recorder erratic (EO)	Work around for EO flights	Repairs made on ground
	Strip chart twice out of ink (EO,CO)	Minor data loss	Refill in flight
	Strip chart malfunctions twice (EO,PI)	Minor data loss both times	Adjust in flight
Data processors	Computer lockup (PI)	Some data loss one flight	Repair after flight
	Computer lockup (EO)	Unknown data quality+	Repair after flight
	Computer will not start twice (CO,EO)	Total data loss two flights+	Repair after flight

CATEGORY II - INFLIGHT MALFUNCTIONS OF EXPERIMENTS - Concluded

Component or System	Problem Definition	Impact	Resolution
Data processors (concluded)	Computer output errors (EO)	Minor time loss	Stop and restart in flight
	Computer lock up twice (EO)	Some data loss both times	Stop and restart in flight
	Computer won't write on strip chart twice (EO)	Minor data loss both times	Repair after flight
	Computer won't write on magnetic tape twice (EO)	Some data loss both times	Reload program
	Computer malfunctic (CO,EO)	Computer use limited (nine flights); real-time data reduction limited	Loose PCB located and fixed after simulation period
	Computer won't accept calibration data (EO)	No data loss; at end of flight	Repair on ground
Control systems	Mirror drive jammed several times (EO)	Nuisance value	Free and restart
	Insufficient motor torque in telescope system (CO)	On-site fix required; some data loss three flights+	Reduce driving forces by covering open port; aerodynamic redesign to reduce forces
	Manual guidance of telescope not possible (CO)	No astronomical data on nine flights+	Mount gyrostabilized mirror in system
	Low sensitivity of star tracker (ALL)	Tracking limited to bright objects on all flights+	Abandon dim targets, switch to skyglow measurements

* EMI problems listed in Category V

\+ Notably serious impact; correction necessary to continue research

(CO) Checkout flights

(EO) Simulation flights

(PI) Postsimulation flights

(ALL) All flights

CATEGORY III - PROBLEMS WITH EXPERIMENT SUPPORT SYSTEMS (GFE)

System	Problem Definition	Impact	Resolution
Ground power supply	Voltage ripple and spikes	Interfered with experiment checkout procedures	Adjust controls, then replace unit; never completely resolved
Ground cooling supply	Faulty operation under partial loading	Experiment overheating slows final integration tests	Controls modified for operation during simulation period
Aircraft 60 Hz supply	Voltage change under transient loads Failure of two 60 Hz inverters	Fuses failed in one experiment with small data loss None; did not fail during data acquisition periods	Add voltage control transformer to experiment Replace one unit; use spare capacity to power experiment
Vacuum system	Insufficient capacity Pump instability	Experiment sensitivity reduced Erratic data records	Reduce leaks; accommodate to higher absolute pressure Replace vacuum pump
Dry N_2 purge	Purge interrupt during refill	Condensation on cooled optics may degrade UV signals	Change procedures to assure continuous supply
Optical viewing ports	Condensation in flight Surface contamination	Serious signal degradation for five experiments UV, IR signal distortion	Improve purge gas distribution system and procedures Clean both surfaces before each flight
Intercom system	EO movement hampered by cabling during experiment operations	Interrupted communications with Mission Manager	Not satisfactorily resolved; alternate procedures developed

...UCIBILITY OF THE
...L PAGE IS POOR

CATEGORY IV - CENTRAL DATA SYSTEM (GFE) CONSTRAINTS

Functional Area	Problem Definition	Impact	Resolution
Signal interface with experiment	Digital data rate limited by sampling rate, 500/sec/ channel	Impractical to use ADDAS, plan local data processing in experiment	Use minicomputer in experiment; alternate CRT displays and plotters
	Total data rate limited by input buffers, 5000/sec digital and digitized analog data	Priority experiment preempts much of available capacity	Switch to conventional tape recorder for primary data
	Interface boxes mal- function	Delay ADDAS/experiment checkout	Add by-pass capacitors
	Two signal cables miswired	Delay ADDAS/experiment checkout	PI teams repair
	Low level signals not acceptable	No measurement of IR window temperatures obtained on first nine flights	Amplifiers built by PI team
Data processing and control signal output	Capacity for detailed operations in flight (real-time) limited by available core size*	Not made clear to PIs. Their plans could not be fully implemented	Simplify real-time data proces- sing. Drop request for feed- back control of one experiment
Software development	Coordination with PIs	Program definition delay critical; advance planning minimal	Concentrate during experiment integration at Ames, cut down where permitted
	Manpower constraints (ADDAS personnel)	On-line processing of exper- iment data delayed and sporadic	Debug and operate programs as time permits
On-line checkout	Experiment checkout delays impact ADDAS integration	Final testing and subsequent operation on early flights both delayed and interrupted	Problems resolved ad hoc basis

CATEGORY IV - CENTRAL DATA SYSTEM (GFE) CONSTRAINTS - Concluded

Functional Area	Problem Definition	Impact	Resolution
Operation in flight	Internal malfunctions interrupt some or all functions	Gaps in flight parameter records, time code signals, and voice comments Loss of TV monitor system Loss of experiment data records Loss of real-time data processing	Reload programs and restart. Selective omission of faulty programs (e.g., Fourier transforms). Debug between flights. Never completely resolved
Post-flight processing	6-hr turnaround time for flight data (two experiments) not fully implemented	PI planning with only partial results from previous flights	Not satisfactorily resolved; PI works with available information
Flight record printouts	Insufficient information for PI evaluation of experiment malfunctions	Solution of experiment malfunctions delayed with impact on EO workload	Increase inflight commentary for better problem description

*Data processing unit only partly utilized; software not available for full 24,000 word memory.

CATEGORY V - EMI/EMC PROBLEMS

Source	Problem Definition	Impact	Resolution
Aircraft VHF radio	RF pickup by detector	Noise spikes in interferometer data complicate processing and reduce quality	Improved by mesh shielding of detector but not eliminated
	RF pickup in cabling	Significant degradation of data in one experiment	Minor improvement by shielding
Electromagnetic fields in cabin	Distortion of image intensifier pictures by ambient magnetic field	Complicates data interpretation	Realigned leads to reduce effect but not eliminated. Discrete source not identified
Aircraft power systems	Radiated noise pickup by detectors in two experiments	Some degradation of data quality	Added shielding made some improvement; install filters
	ADDAS printer generates line pulses that are widely distributed	Signal noise at most experiments, but only minor degradation of data quality	Data system powered from separate 60-Hz inverter to reduce effects
Central data system (ADDAS)	Anticipated ground loop feedbacks	Very small pickup observed, but can be ignored	Isolate experiment from data system with optical coupler (in original design)
Experiment components	Anticipated cross talk and ground loops between experiments	None observed	Design experiments for component isolation from racks with single-point ground

CATEGORY VI - SCHEDULE AND TIME-SHARING CONSTRAINTS

Area of Concern	Problem Definition	Impact	Resolution
Research scheduling	Start-up sequence for three experiments	Loss of observing time	EO optimizes procedures; assistance from another EO
	Simultaneous operation of several experiments by EO	Limited observing time	Preflight agreement by PIs
	Share common optical systems	Limited observing time on astronomical targets	Premission agreement by PIs. Daily preflight decision by PIs. Inflight decision by EO based on experiment performance
	Flight route planning to accommodate divergent requests	Limited observing time; decisions by Mission Manager	Premission definition of experiment priorities. Unique requirements of all experiments accommodated on at least one flight. Inflight adjustments to route (when possible) by special request to Mission Manager
	LHe supply exhausted in dewar; no provision by PI for two-section flight	Half of data lost on one flight	None
Experiment maintenance	Equipment malfunction increases EO workload in flight	Loss of data from one or more experiments	EO decision to shut down; assistance from another EO to troubleshoot and repair
	Communication system overload, EO to PI, on the ground	Critical delay in solving equipment malfunction	Designate priority use and set time limits for others

CATEGORY VII - VEHICLE OPERATIONS CONSTRAINTS

Area of Concern	Problem Definition	Impact	Resolution
Vehicle stability	Roll instability	Loss of target and data on stabilized telescope	Reacquire target when stable
		Smeared records on fixed position cameras	Roll excursion effect reduced by short exposure time
	Air turbulence	Infrequent occurrence felt by all; data lost	Wait out
Positional limits	Celestial light sources mask skyglow signals in viewing direction	Substantial down time for two experiments	Move one experiment left to right side; cease observations on the other
	Below tropopause at low latitudes required for astronomical targets	Atmospheric water vapor degrades data quality for several experiments	Emphasize measurements obtained when above tropopause
	High clouds or storms in flight path	Little data acquisition	Move to parallel flight path or climb to higher altitude
Flight-time constraint	Light level too high for observation	No data acquisition	None; result of time-shared flight schedule
Cabin environment	Computer overheats and shuts down	Some loss of data	Reduce cabin temperature and restart unit when cool
	Spectrometer drive linkage stalls when too cold. Heat conduction to cold structure causes problem	Minor data loss; requires continuous monitoring	Apply heat locally to restart